AMERICAN WATER WORKS LABORATORIES[1]

By Jack J. Hinman, Jr.

The water works laboratory as an integral part of the up-to-date water works plant is so well established and has proved itself so useful that any attempt on the author's part to justify its existence is unnecessary. It is only where the small size of the plant forbids the expense attached or where an invariable ground water is supplied that the lack of daily laboratory control should be excused.

While an experienced operator will probably be able to judge the character of the water supply on most occasions, there are, nevertheless, times when a clear, sparkling water may be carrying large numbers of bacteria some of which may be pathogens, or disease-producing forms. The only way to know the quality of the effluent is to submit it to a laboratory examination. At best the delays incident to cultural methods are considerable, but to pump a dangerous water until typhoid cases commence to develop in a community before having examinations undertaken is inexcusable. The number of examinations which it is advisable to make will depend, naturally, on the supply. If the supply is from deep wells, fewer examinations will be required than where the supply is from shallow wells and infiltration galleries. Where a polluted water is coagulated and filtered, examinations should be made even more frequently than in the case of the shallow wells and infiltration galleries. It should be remembered that a dangerous water is being treated and that the character of the effluent may change from day to day or even from hour to hour.

Then, too, the mere installation of a laboratory does not confer immunity from raw water troubles or even from the more serious difficulties. An accumulation of glassware collecting dust is of no value, neither is an accumulation of figures which have no significance from the standpoint of the quality of the effluent or of the effective operation of a plant. Most analysts run a few thousand nitrogen determinations on the raw water before realizing that the

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results do not vary enough from day to day to be of any practical value. To run them as a routine measure in such cases is a waste. Under certain conditions, of course, there may be considerable daily variations in the nitrogen factors. It is essential that the variable factors be recognized, so that changes in the raw water may be detected and the treatment altered to meet the new conditions. More elaborate examinations of the treated water are justified as giving additional evidence as to its satisfactory character.

For some time the author has been curious to know about the water laboratories which serve the various water plants directly. He was not so much interested in the laboratories that did work under contract or with those that made occasional examinations. He wished to know what plants maintained laboratories, how extensive they were, how they were organized, what their routine procedures were and what results were obtained. He sent out a very comprehensive questionnaire to all cities of over 25,000 population in the United States and Canada, as well as to some smaller places where he knew laboratories were maintained or rapid sand filtration plants installed. Only those which reported plant or department laboratories are included in this report. Contract laboratories and plants operating without laboratory control are not included in the tables.

The percentage of replies was very good. There are only four or five towns of special interest which failed to answer the letters. The author has data on an average daily pumpage of more than 3,000,000,000 gallons, of which more than 2,800,000,000 gallons, supplying cities and towns of a total population of about 17,000,000 in 1910, is protected by laboratory control directly under the supervision of the water works officials or their superior officers.

In the control of the 96 plants which supply the 2,800,000,000 gallons of water daily, 203 laboratory workers are employed. Of these, 95 have the title of chemist or assistant chemist, many of the others have the title superintendent of filtration or laboratory director, and so on. Some of these men have had chemical training. Some are engineers who have picked up the rudiments of water examination and carry on such determinations as are necessary for their plants. The preponderance of one-man laboratories is significant and the variety of the work which must be performed is worthy of notice. In addition to the widely differing subjects of bacteriology, microbiology and chemistry of water, miscellaneous chemical

STATE	CITY	POPULATION IN 1910	AVERAGE DAILY SUPPLY MILLIONS OF GALLONS	SOURCE
California	Los Angeles	319,198	75.0	Aqueduct and River
	Pasadena	30,291	5.8	Ground and surface
Colorado	Colorado Springs	29,078	6.1	Mountain streams and reservoir
	Denver	213,281	52.0	Lake Cheesman and infiltration
Connecticut	Hartford	98,915	11.1	Six reservoirs
District of Columbia"	Washington	331,069	59.9	Potomac River
Georgia	Atlanta	154,839	18.1	Chattahoochee River
	Columbus	20,554	2.3	Chattahoochee River
Illinois	Cairo	14,548	4.25	Ohio River
	Chicago	2,185,283	700.0	Lake Michigan
	Danville	27,871	5.37	North Fork Vermillion River
	Decatur	31,140	3.93	Sangamon River
	Elgin	25,976	1.50	Five wells, 42 feet to 2000 feet.
	Evanston	24,978	8.5	Lake Michigan
	Moline	24,199	4.0	Mississippi River
	Quincy	36,587	2.0	Mississippi River
	Streator	14,253	....	Vermillion River
Indiana	Evansville	69,647	9.0	Ohio River
	Ft. Wayne	63,933	6.0	Deep wells
	Indianapolis	233,650	24.31	Filtered surface and deep wells
	Terre Haute	58,157	5.0	Wabash River
	Valparaiso	6,087	0.8	Chain of small lakes
Iowa	Cedar Rapids	37,811	3.0	Cedar River and 1500 feet wells
	Council Bluffs	29,992	3.25	Missouri River
	Davenport	43,028	4.14	Mississippi River
	Des Moines	86,386	6.9	Ground water, Valley of Raccoon River
Kansas	Atchison	16,429	1.2	Missouri River
Kentucky	Louisville	223,928	26.0	Ohio River
Louisiana	Morgan City	5,477	0.25	Atchafaloya River
	New Orleans	339,075	30.0	Mississippi River
Massachusetts	Brockton	56,878	2.9	Silver Lake
	Lowell	106,294	6.0	2½-inch driven wells
Michigan	Bay City	45,166	7.0	Saginaw River and Bay
	Grand Rapids	112,571	12.35	Grand River

... URCE	OWNERSHIP	TITLE OF LABORATORY CHIEF	HIS IMMEDIATE SU...
	Municipal	Laboratory director	Commissioner
	Municipal	City chemist	Commissioner public works
...d reservoir	Municipal	City chemist and bacteriologist	Commissioner public health
infiltration	Private	Chemist	....
	Municipal	Chemist and bacteriologist	Chief engineer
	U. S. Government	Chemist	Superintendent
	Municipal	Chemist	General manager
	Municipal	Assistant superintendent	Engineer and superintendent
	Private	Manager and superintendent	....
	Municipal	Director municipal laboratories	Commissioner of health
...on River	Private	Chief engineer	Superintendent
	Municipal	City chemist	Commissioner
2000 feet.	Municipal	(In city laboratory)	....
	Municipal	Superintendent of filtration	Commissioner public works
	Municipal	City chemist	Commissioner public property
	Municipal	Superintendent	Board water commissioners
	Private	Chief engineer	....
	Municipal	Chemist	General manager
	Municipal	(In city laboratory)	....
deep wells	Private	Superintendent of filtration	General manager
	Private	Chief engineer	Water Company
	Private	Chief engineer	....
...) feet wells	Municipal	Sanitary engineer and city chemist	Boards water commissioners an...
	Municipal	Chemist	Superintendent
	Private	Chief engineer (under consulting chemist)	Superintendent
...y of Raccoon River	Private	Chief chemist	Superintendent
	Private	....	....
	Municipal	Superintendent of filtration	Chief engineer
	Municipal	Superintendent water purification stations	Council
	Municipal	Superintendent	General superintendent sewera...
	Municipal	City Bacteriologist and chemist	Superintendent
	Municipal	Engineer in charge filtration	Superintendent and commissi...
...ay	Municipal	Chemist	Superintendent
	Municipal	Chief chemist and superintendent	Board of public works

TABLE 1

American Water Works Labc

HIS IMMEDIATE SUPERIOR	ADDITIONAL LABORATORY WORKERS			CIVIL SERVICE	Counting	
	Chemists	Bacteriologists	Helpers		37°C.	20° C. to room
iissioner	1	....	....	Yes	†	†
iissioner public works	1	....	....	No	Agar 48 hours	Agar 48 hours, r ture
iissioner public health	....	....	....	Yes	Agar 24 hours	Agar 48 hours, 2
....	....	....	....	....	Agar 24 hours	Gelatine 48 hou:
engineer	1	....	....	....	....	....
ntendent	1	....	2	Yes	....	Gelatine 48 hou:
al manager	....	....	....	No	Agar 24 hours	....
eer and superintendent	....	....	....	No	Agar 24 hours	....
....	....	....	2	No	Agar 24 hours	....
iissioner of health	....	....	3	Yes	Agar 24 hours	Agar and gelatir
ntendent	....	....	1	No	Agar 24 hours	....
issioner	....	....	....	No	Agar 24 hours	Gelatine 48 houı
....	....	....	....	....	Agar —	....
iissioner public works	....	....	1	Yes	L. Lactose and plain agar 24 hours	Gelatine 48 hou
issioner public property	....	....	....	No	....	Agar 48 hours, 2
water commissioners	....	....	....	No	Agar 24 hours	....
....	....	....	....	....	Agar —	....
il manager	....	....	....	No	Agar —	Gelatine 20°
....	....	....	....	....	....	....
il manager	2	....	2	....	Agar 24 hours	Gelatine 20°
Company	....	....	1	....	Agar, maximum development	Gelatine, maxin ment
....	....	....	....	....	Agar —	Gelatine —
ı water commissioners and health	....	....	....	....	Agar 24 hours	Gelatine 48 houı
ntendent	....	....	....	No	....	Agar 72 hours, r ture
ntendent	....	....	....	....	....	Gelatine 48 houı
ntendent	1	....	....	....	Agar 48 hours	Agar 72 hours, 2
....	....	....	....	....	....	....
engineer	1	1	....	No	L. lactose agar 24 hours	Gelatine 48 houı
il	....	....	....	No	Agar 24 hours	....
il superintendent sewerage and water board	2	1	....	Yes	Agar 24 hours	Gelatine 48 houı
ntendent	1	....	1	Yes	Agar (L. lactose) 24 hours	....
ntendent and commissioner	1	....	....	Yes	....	....
ntendent	....	....	....	No	....	"Bacterial coun
of public works	3	....	....	No	Agar 24 hours	Agar 48 and 72

TABLE 1

Water Works Laboratories. (*Routine*)

	BACTERIOLOGICAL PROCEDURE				
Counting		B. coli tests		PLANKTON EXAMINATIONS	
	20° C. to room temperature	Fermentation media	Confirmatory		
	†	......	Gas; endo; gelatine	Yes	Nitr
	Agar 48 hours, room temperature	Lactose bile	Gas; Litmus lactose agar	No	Occa
	Agar 48 hours, 22°C.	......	Gas; L. lactose agar; lactose milk; gelatine	No	Sani
	Gelatine 48 hours, 20°	Lactose bile Lactose broth	Gas; L. lactose agar; lactose broth		Sani
......	......	......			Com
......	Gelatine 48 hours	......	"Confirmatory"	Yes	Nitr
	......	Lactose broth	......	No	Alka
	......	Lactose broth Lactose broth	Gas; L. lactose agar; lactose broth	Will	Alkal
	......	Lactose bile Dextrose broth	5 per cent gas	Occasionally	Alkal
	Agar and gelatine 48 hours	Lactose bile	Gas; indol; esculin; endo plates	No	Nitr
	......		Endo	No	Alkal
	Gelatine 48 hours, 20°		Gas	No	Nitr
	......	Dextrose broth	Gas; endo; morphology	No	Iron
plain	Gelatine 48 hours, 20°	Lactose broth	Gas and acid colonies	Yes	Avail
......	Agar 48 hours, 20°	Dextrose broth	10 per cent gas	Quarterly	Sanit
	......	Lactose broth	10 per cent gas	No	Alkal
	......	Dextrose broth	Gas	No	No
	Gelatine 20°	Lactose broth	Gas; endo; bile	Occasionally	Alkal
......	......	Lactose and glucose media	......	No	No
	Gelatine 20°	......	†1917	No	Sanit
de-	Gelatine, maximum development	......	Gas. U. S. P. H. method	No	Alkal
	Gelatine —	Lactose bile	20 per cent gas; L. lactose agar; endo; indol	No	Alkal
	Gelatine 48 hours	Lactose broth	10 per cent gas	Seldom	Alkal
......	Agar 72 hours, room temperature	Lactose broth	Gas in 72 hours	No	Sanit
......	Gelatine 48 hours, 20°	......	......	No	Alkal
	Agar 72 hours, 20°	Lactose broth	U. S. P. H. method	No	Fe, h yea
......	......	......	......	......	Alkal
r 24	Gelatine 48 hours	Lactose bile	10 per cent gas, "complete isolation"	Occasionally	Alkal
	......	Broth	5 per cent gas	No	Alkal
	Gelatine 48 hours, 20°	......	U. S. P. H. method	No	Alkal
) 24	......	......	Gas; indol	Yes	Fe, se
......	......	......	......	No	Fe, a
......	"Bacterial count"	Lactose broth	Gas; endo; agar slant	Yes	Avail
	Agar 48 and 72 hours, 20°	Lactose broth	†1917	Yes	Alkal

PLANKTON EXAMINATIONS	CHEMICAL DETERMINATIONS	PHYSICAL DETERMINATIONS	DATE LABORATORY CONTROL BEGUN
Yes	Nitrogen, chlorine, total solids, hardness	Turbidity, color, odor, taste	1915
No	Occasional complete mineral and sanitary	No	1912
No	Sanitary	Odor, color, taste, etc.	1902
	Sanitary analysis once a month	color, turbidity, taste, odor, sediment	....
	Complete sanitary	Color, turbidity, taste, odor, sediment	1913
Yes	Nitrogens, hardness alkalinity, chlorine	Turbidity	1915
No	Alkalinity	Turbidity	1915
Will	Alkalinity, CO_2	Turbidity, color, odor, taste	1915
Occasionally	Alkalinity	Turbidity, color, etc.	1913
No	Nitrogens, oxygen consumed, chlorine	....	....
No	Alkalinity	Turbidity, color	1912
No	Nitrogens, solids, chlorine, oxygen consumed, alkalinity	Turbidity, color, odor	1916
No	Iron	Sediment	....
Yes	Available chlorine, oxygen dissolved, alkalinity	Turbidity, odor, temperature	1914
Quarterly	Sanitary monthly, mineral quarterly, alkalinity, hardness	Turbidity, odor, temperature	1903
No	Alkalinity	Turbidity color	1909
No	No	....	1910
Occasionally	Alkalinity, CO_2: hardness, Mg. monthly	Turbidity, color, odor, temperature	1912
No	No	Odor, sediment	....
No	Sanitary and mineral analyses	Turbidity, color, odor, taste	1904
No	Alkalinity, chlorine, CO_2, hardness	Turbidity, color, odor, taste, temperature	1908
No	Alkalinity. Occasionally CO_2, NO_2, chlorine, Fe	Color	1909
Seldom	Alkalinity, chlorine, oxygen consumed	Turbidity, color, odor, taste	1912
No	Sanitary two to three times month	Color, suspended matter	1909
No	Alkalinity	Turbidity, color	1910
No	Fe, hardness daily; sanitary two per week; mineral two per year	Color, turbidity, odor, taste	1911
....	Alkalinity	Turbidity	....
Occasionally	Alkalinity 2 times day; sanitary weekly; mineral monthly	Turbidity, temperature	1909
No	Alkalinity, chlorine	Turbidity, color	1916
No	Alkalinity, CO_2, chlorine, incrustants, solids	Turbidity, color, odor	1909
Yes	Fe, sanitary	Turbidity, color	1906
No	Fe, alkalinity, Mn, CO_2, dissolved oxygen	Turbidity, color	1915
Yes	Available chlorine, oxygen consumed	Turbidity, taste	1916
Yes	Alkalinity, Mg, incrustants, hourly to 3 times day	Turbidity, color, odor (hot and	1912

MINATIONS	DATE LABORATORY CONTROL BEGUN	EXAMINATIONS OTHER MATERIALS	WORKING STANDARD
lor, taste	1915	Occasionally	U. S. Treasury Department for interstate carriers
	1912	Sewage, food, oils, etc.	"Total bacteria less than 20 per cubic centimeter"
tc.	1902	Health department work	"48 hour count under 100"
taste, odor,	....	No	U. S. Treasury Department for interstate carriers
taste, odor,	1913	No	"Colon negative in 10 cc."
	1915	....	"As high as possible"
	1915	Coal, chemicals, etc.	"Under 15 per cubic centimeter"
lor, taste	1915	Filter chemicals	"As low as possible in bacteria and B. coli"
c.	1913	Filter chemicals	U. S. Treasury Department
....	....	Miscellaneous for department	"Free of colon in 10 cc.
	1912	No	U. S. Treasury Department
lor	1916	Food, sewage	U. S. Treasury Department
	....	Pathological work	....
nperature	1914	No	"Very few colonies on gelatine, no gas in fermentation tubes, no color, turbidity, chlorine, alum
nperature	1903	Health and street departments	"Bacteria near 0, gas absent in 1 cc. and 4/5 of 10 cc. tubes, color 15 turbidity 0"
	1909	No	"Agar count below 50; B. coli absent in 10 cc."
....	1910	....	"Below a count of 50 bacteria in 1 cc. and negative gas tests"
dor, tempera-	1912	....	U. S. Treasury Department
	....	Health department work	....
or, taste	1904	Coal, sand, chemicals	U. S. Treasury Department
or, taste, tem-	1908	No	"Bright and clear"
	1909	No	U. S. Treasury Department
or, taste	1912	Milk, gas, etc.	U. S. Treasury Department
atter	1909	Coal, chemicals	"No gas-forming bacteria; less than 50 bacteria per cubic centimeter as little color and turbidity as possible"
	1910	No	"As nearly sterile as possible"
or, taste	1911	Sand, milk	"No fermentation in 10 cc.; 75 bacteria per cubic centimeter at 20°C"
	....	....	....
;ure	1909	Sand, chemicals	"Less than 100 bacteria per cubic centimeter; no B. coli in two 1 and two 10 cc. plantings"
	1916	No	"Negative for B. coli; 98 to 100 per cent bacteria removal; turbidity 0"
or	1909	Supplies	U. S. Treasury Department
	1906	General city work	....
	1915	No	Fe and Mn absent (plant for Fe and Mn removal only)
	1916	General bacterial work	....
dor (hot and	1912	General city work	"Alkalinity and turbidity; hardness as low as raw water permits,

Kansas	Atchison	[illegible]	[illegible]	Missouri River
Kentucky	Louisville	223,928	26.0	Ohio River
Louisiana	Morgan City	5,477	0.25	Atchafaloya River
	New Orleans	339,075	30.0	Mississippi River
Massachusetts	Brockton	56,878	2.9	Silver Lake
	Lowell	106,294	6.0	2½-inch driven wells
Michigan	Bay City	45,166	7.0	Saginaw River and Bay
	Grand Rapids	112,571	12.35	Grand River
Minnesota	Minneapolis	301,408	30.0	Mississippi River
Missouri	St. Louis	687,029	98.0	Mississippi River
	Springfield	35,201	4.0	Springs and deep wells
Nebraska	Omaha	124,096	20.0	Missouri River
New Jersey	Paterson, etc.	125,600	37.0	Passaic River
	Trenton	96,815	17.5	Delaware River
New York	Albany	100,253	20.0	Hudson River
	Auburn	34,668	6.5	Owasee Lake
	Kingston	25,908	4.5	Sawkill Creek
	Mt. Vernon	30,919	2.5	River
	Newburgh	27,805	5.13	Lake
	New York	4,766,883	550.0	Surface and ground supplies
	Niagara Falls	30,445	10.5	Niagara River
	Poughkeepsie	27,936	2.54	Hudson River
	Schenectady	72,826	11.16	Three dug wells
	Syracuse	137,249	....	Skaneatles Lake
	Utica	74,419	12.5	West Canada Creek, etc.
	Watertown	26,730	5.5	Black River
	Yonkers	79,803	9.0	Nepperhan River, Grassy Sprain Branch
North Carolina	Wilmington	25,743	3.0	Cape Fear River
Ohio	Akron	69,069	20.0	Cuyahoga River
	Alliance	15,083	6.0	Mahoning River
	Bucyrus	8,122	1.5	Reservoir
	Cincinnati	363,591	50.0	Ohio River
	Cleveland	560,663	96.0	Lake Erie
	Columbus	181,511	20.0	Scioto River
	Dayton	116,577	12.9	Deep wells
	Denison	4,008	2.0	Big Stillwater Creek
	Lima	30,508	3.5	Ottawa River
	Niles	8,361	1.5	Mahoning River
	Sandusky	19,989	4.5	Sandusky River

	Municipal	Superintendent of filtration	Chief engineer
	Municipal	Superintendent water puiification stations	Council
	Municipal	Superintendent	General superintendent seweraę
	Municipal	City Bacteriologist and chemist	Superintendent
	Municipal	Engineer in charge filtration	Superintendent and commissic
ɜay	Municipal	Chemist	Superintendent
	Municipal	Chief chemist and superintendent	Board of public works
	Municipal	Chemist and assistant superintendent	Superintendent purification di
	Municipal	Chemist	Engineer in charge supply and p
lls	Private	....	Company
	Municipal	Sanitary chemist	General manager
	Private	Superintendent filtration and pumping	Company
	Municipal	Superintendent filtration	Director Street and Public In
	Municipal	Chemist	Contract chemist
	Municipal	City bacteriologist	City health and water departı
	Municipal	Chemist and bacteriologist	City Superintendent
	Private	Engineer	Superintendent
	Municipal	Superintendent of water shed	City manager
upplies	Municipal	Two directors of laboratory	Chief engineer
	Municipal	Chemist in charge operation	Superintendent public service
	Municipal	Bacteriologist	Commissioners and superintenc
	Municipal	City chemist	....
	Municipal	City Bacteriologist	....
ɜtc.	Private	Biologist	Executive committee of compa
	Municipal	Superintendent water purification plant	Board water works
·assy Sprain Bianch	Municipal	Chemist department public works	Commissioner public works
	Municipal	Director, board of health laborator	Board of health
	Municipal	Chief chemist	Superintendent
	Municipal	City chemist	Director public service
	Private	....	....
	Municipal	Bacteriologist and chemist	Superintendent filtration
	Municipal	Chief chemist and bacteriologist	Superintendent filtration
	Municipal	Chemist in charge	Superintendent
	Municipal	Chemist and bacteriologist	Commissioner health
	Private	Superintendent	Directors of company
	Municipal	City chemist	Service director
	Municipal	Filtration expert	Superintendent
	Municipal	Chemist in charge	City manager

...						
ngineer	1	1	...	No	L. lactose agar 24 hours	Gelatine 48 hou
l	...	...	...	No	Agar 24 hours	...
l superintendent sewerage and water board	2	1	...	Yes	Agar 24 hours	Gelatine 48 hou
ntendent	1	...	1	Yes	Agar (L. lactose) 24 hours	...
ntendent and commissioner	1	...	...	Yes	...	...
ntendent	...	...	...	No	...	"Bacterial coun
of public works	3	...	...	No	Agar 24 hours	Agar 48 and 72 Gelatine 48 hou
ntendent purification division	...	1	1	Yes	Agar 24 hours	Agar 48 and 72 Gelatine 48 hou
eer in charge supply and purification division	2	2	4	Efficiency board	Agar 24 hours	Gelatine 72 hou
ny	3	...	...	...	...	Gelatine 48 hou
l manager	1	...	...	No	...	Gelatine 48 hou
	1		1			Gelatine 20°
ny		...		...	Agar 24 hours	
			1			ou'
or Street and Public Improvement	...	...		Yes	...	Agra 48 hours, 2
			1			
ct chemist	2	...		Yes	Agar 24 hours, 40°	Gelatine 48 hour
ealth and water departments	...	...	...	Yes	Agar 24 hours	Gelatine 48 hou
uperintendent	...	...	...	...	Agar 24 hours	Gelatine 72 hour
ntendent	...	...	...	...	...	Agar 48 hours, 2
anager	...	...	...	Yes	Agar 24 hours	...
ngineer	3	3	12	Yes	Agar 24 hours	...
tendent public service	...	...	1	Yes	...	Gelatine 48 hour
issioners and superintendent public works	...	...	...	Yes	Agar 24 hours	Gelatine 48 hour
...	...	...	...	...	...	Agar 48 hours, 2
...	...	...	...	...	...	...
ive committee of company	...	...	1	...	Agar 24 hours	Gelatine 24 and
water works	...	...	...	Yes	...	Gelatine, 20°
ssioner public works	1	...	...	Yes	...	Gelatine, 20°
f health	...	...	...	No	...	...
tendent	1	...	1	Yes	L. lactose and plain agar 24 hours	Gelatine, 20°
r public service	...	...	...	Yes	L. lactose and plain agar 24 hours	Agar 48 hours, 2
...	...	...	...	...		
tendent filtration	1	...	1	...	...	Gelatine 48 hour
tendent filtration	...	1	2	Yes	Agar 24 hours	...
tendent	3	...	...	Yes	Agar 24 hours	— 48 hours, 20°
ssioner health	1	...	1	...	Agar 24 hours	Agar 48 hours, 2
s of company	...		...	...	Agar —	Gelatine —
director	...	...	...	No	...	Agar, room temp
tendent	...	...	...	No	Agar —	Gelatine
nager	...	...	...	Yes	...	Agar 48 hours, 2

r 24	Gelatine 48 hours	Lactose bile	10 per cent gas, "complete isolation"	Occasionally	Alkal
	......	Broth	5 per cent gas	No	Alkal
	Gelatine 48 hours, 20°	......	U. S. P. H. method	No	Alkal
ə) 24	......	......	Gas; indol	Yes	Fe, se
......	......	......	......	No	Fe, a
......	"Bacterial count"	Lactose broth	Gas; endo; agar slant	Yes	Avail
	Agar 48 and 72 hours, 20° Gelatine 48 hours, 20°	Lactose broth	†1917	Yes	Alkal
	Agar 48 and 72 hours, 20° Gelatine 48 hours, 20°	Lactose broth	Gas; run through sugars, etc	Weekly	Alkal tar
	Gelatine 72 hours	Lactose broth	Gas; endo; lactose broth	No	Alkal mo
......	Gelatine 48 hours, 20°	Lactose broth	10–70 per cent gas; 50 per cent of this in 24 hours	......	Alkal
......	Gelatine 48 hours, 20°	Lactose broth	20–70 per cent gas in 48 hours	No	Alkal
	Gelatine 20°		Gas; agar; indol; nitrate; milk	No	
		......			Daily
	ou'		Gas; endo	No	tar
......	Agra 48 hours, 20°	Broth			CO_2,
ı°	Gelatine 48 hours, 20°	Dextrose broth and bile	Gas; L. lactose agar, indol; gelatine	Summer only	Daily am
	Gelatine 48 hours, 20°	Lactose bile	Gas	No	No
	Gelatine 72 hours, 20°	......	Gas 48 hours, 20–70 per cent; 50 per cent in 24 hours	Yes	Alkal
......	Agar 48 hours, 20°	Lactose bile	Gas	No	No
	......	Lactose bile	Gas in 48 hours	......	No
	......	Lactose bile	Gas in 72 hours, 20 per cent	Yes	Sanit
......	Gelatine 48 hours, 20°	Lactose bile	Gas † 2nd Edn.	No	Alkal
	Gelatine 48 hours, 20°	Lactose bile	Gas in 48 hours	No	Alkal
......	Agar 48 hours, 20°	......	......	......	Occas
......	......	......	......	......	......
	Gelatine 24 and 48 hours	Lactose bile	Gas	No	Alkal
......	Gelatine, 20°	Lactose bile	Gas	No	Alkal
......	Gelatine, 20°	......	20–70 per cent gas; 25–40 per cent CO_2	Occasionally	Comp
......	......	......	†	Seldom	Alkal
plain	Gelatine, 20°	Lactose bile	15 per cent gas, L. lactose agar	Yes	Alkal
plain	Agar 48 hours, 20°	Lactose bile	Gas 10 per cent	Occasionally	Alkal chl
			......	......	No
......	Gelatine 48 hours, 20°	Lactose bile	Gas endo; lactose broth; gelatine; Gram, morphology	Occasionally	Alkal tion
	......	Lactose broth	Gas; endo; lactose broth; gelatine; Gram; morphology	Occasionally	Alkal
	— 48 hours, 20°	Lactose	Gas in bile; broth; saccharose, dulcite	No	Alkal
	Agar 48 hours, 20°	Lactose broth	5 per cent gas; endo; Lactose broth; 5 per cent gas	No	Hard
	Gelatine —	Lactose broth	......	No	Alkal
......	Agar, room temperature	Dextrose broth Lactose bile	Gas in bile and broth, gelatine, nitrate, indol	No	No
	Gelatine	......	Gas in 48 hours	No	Alkali
......	Agar 48 hours, 20°	Lactose bile	Gas	No	Alkali

Occasionally	Alkalinity 2 times day; sanitary weekly; mineral monthly	Turbidity, temperature	1909
No	Alkalinity, chlorine	Turbidity, color	1916
No	Alkalinity, CO_2, chlorine, incrustants, solids	Turbidity, color, odor	1909
Yes	Fe, sanitary	Turbidity, color	1906
No	Fe, alkalinity, Mn, CO_2, dissolved oxygen	Turbidity, color	1915
Yes	Available chlorine, oxygen consumed	Turbidity, taste	1916
Yes	Alkalinity, Mg, incrustants, hourly to 3 times day	Turbidity, color, odor (hot and cold,	1912
Weekly	Alkalinity, hardness, CO_2, dissolved oxygen, monthly sanitary and mineral	Turbidity, color, taste	1913
No	Alkalinity, Ma, Ca, solids, sanitary weekly, mineral 2 times monthly	Turbidity, color	1906
....	Alkalinity, chlorine, free chlorine, alum	Turbidity, color	1911
No	Alkalinity, chlorine, sanitary	Turbidity, color	1911
No			
	Daily CO_2, dissolved oxygen, 2 times day, alkalinity; sanitary monthly	Turbidity, color	1902
No	CO_2, alkalinity	Turbidity, color	....
Summer only	Daily CO_2, alkalinity, hardness, chlorine, oxygen consumed, ammonias	Turbidity, color, temperature	1899
No	No	No	1913
Yes	Alkalinity, hardness, chlorine	Turbidity, color	1912
No	No	No	1911
....	No	....	1915
Yes	Sanitary analyses, alkalinity, solids, etc., total lime	Turbidity, color, temperature	1897
No	Alkalinity hardness, chlorine	Turbidity, color, temperature	....
No	Alkalinity, chlorine	Turbidity, color temperature, odor	1907
....	Occasional sanitary examinations	....	....
....	....	....	....
No	Alkalinity, hardness, chlorine	Turbidity, color, odor, taste	1897
No	Alkalinity	Turbidity, color	1904
Occasionally	Complete sanitary monthly	Turbidity	1913
Seldom	Alkalinity, hardness, chlorine, CO_2	Turbidity, color	1912
Yes	Alkalinity, hardness, CO_2, oxygen consumed; mineral monthly	Turbidity, color	1915
Occasionally	Alkalinity, incrustants, Fe, CO_2, Mg, oxygen consumed, free chlorine	Turbidity, color	1913
....	No	Turbidity	....
Occasionally	Alkalinity, hardness, oxygen consumed, sanitary examinations	Turbidity, color, suspended matter	1907
Occasionally	Alkalinity, chlorine, free chlorine	Turbidity	....
No	Alkalinity, incrustants, CO_2, Mg	Color	1908
No	Hardness, alkalinity, sanitary examinations	Turbidity, color, odor	....
No	Alkalinity, free chlorine, Fe	Turbidity, color	1915
No	No	....	1911
No	Alkalinity, hardness, Fe, etc.	Turbidity, col r, temperature	....
No	Alkalinity; occasionally Fe, chlorine, incrustants	Turbidity, color, temperature	1909

;ure	1909	Sand, chemicals	"Less than 100 bacteria per cubic centimeter; no B. coli in two 1 and two 10 cc. plantings"
	1916	No	"Negative for B. coli; 98 to 100 per cent bacteria removal; turbidity 0"
or	1909	Supplies	U. S. Treasury Department
	1906	General city work	....
	1915	No	Fe and Mn absent (plant for Fe and Mn removal only)
	1916	General bacterial work	....
dor (hot and	1912	General city work	"Alkalinity and turbidity; hardness as low as raw water permits, Mg controlling factor"
ite	1913	No	"Colony count 10 or less; B. coli absent in 10 cc.; color 10; turbidity. taste, odor 0"
	1906	Filter chemicals	"Agar count below 50; no B. coli in 50 cc."
	1911	No	"Free from B. coli and bacterial count as low as possible to obtain"
	1911	Coal, supplies	"Clear, colorless odorless, average count less than 100; B. coli negative in 1 cc."
	1902	No	"Color 10 or less; bacteria 5"
	....	Milk	"Turbidity less than 1; color less than 10; bacteria reduction 99.9 per cent; B. coli not over 10 per cent †"
nperature	1899	Sewage	"Gelatine count under 50; agar under 5; no colonies on neutral red bile agar; not more than 25 per cent of 10 cc. B. coli tubes positive in a year's time"
	1913	No	....
	1912	No	'Gelatine count below 100; color less than 10 p.p.m.; turbidity 0"
	1911	No	"Below an average of 50 bacteria per cubic centimeter"
....	1915	No	"Free from gas in 10 cc."
nperature	1897	Sand, sewage, research	"As free as possible from B. coli in 10 cc."
nperature	....	No	"B. coli negative in 10 cc. volumes; count not over 10"
temperature,	1907	No	"100 per cent"
....	....	....	....
....	....	(Two examinations weekly)	....
or, taste	1897	Supplies, etc.	....
	1904	Occasionally	"Color below 15; bacteria low—less than 20; colon absent"
	1913	Coal	"No B coli in 10 cc.; total microorganims about 15 to 25 per cubic meter on average"
	1912	Diagnostic work	"0.0 per cent B. coli in 10 cc., 37° count below 50; 38° count below 20."
	1915	Coal	"Free from B. coli in 1 cc. and except occasionally in 10 cc.; 20°count less than 100 per cubic centimeter"
	1913	Sewage	"0 turbidity and no colon in 1 cc."
	....	....	....
spended mat-	1907	Supplies	....
	....	Supplies	'As low as possible in bacteria without producing odor and taste of chlorine"
	1908	City supplies	"B. coli absent in 50 cc.; total numbers below 20"
or	....	General city work	"Free of B. coli in 10 cc. and pollution of any kind"
	1915	No	'Negative B. coli in 1 and 10 cc. with not over 50 bacteria per cubic centimeter at 20°C"
....	1911	Milk	"Free from B. coli"
nperature	....	No	"Less than 50 bacteria; free from gas formers in 10 cc."
nperature	1909	Oil, coal, chemicals	"Less than 50 bacteria per cubic centimeter; no B. coli; free from turbidity, color less than 10"

	Dayton	116,577	12.9	Deep wells
	Denison	4,008	2.0	Big Stillwater Creek
	Lima	30,508	3.5	Ottawa River
	Niles	8,361	1.5	Mahoning River
	Sandusky	19,989	4.5	Sandusky River
	Steubenville	22,381	4.2	Ohio River
	Toledo	168,497	21.8	Maumee River
Oregon	Portland	207,214	65.0	Bull Run Lake
Pennsylvania	Allentown	51,913	12.0	Springs
	Erie	66,525	19.0	Lake Erie
	Lancaster	47,227	7.23	Conestoga Creek
	McKeesport	42,694	5.0	Youghiogheny and Monongahela Rivers
	Philadelphia	1,549,008	300.0	Delaware and Schuylkill Rivers
	Reading	96,071	12.62	Creeks, springs, etc.
Rhode Island	Newport	27,149	6.5	Impounded surface
	Providence	224,326	22.5	Pawtuxet River
South Carolina	Charleston	58,833	6.25	Reservoir
	Columbia	26,319	5.5	Congoree River
South Dakota	Huron	5,791	0.5	James River
Tennessee	Nashville	110,364	13.0	Cumberland River
Texas	Dallas	92,104	7.5	....
	Ft. Worth	73,312	5.0	Trinity River
Virginia	Lynchburg	29,494	6.0	Impounding reservoir
	Richmond	127,628	13.35	James River
Washington	Spokane	104,402	32.0	....
Wisconsin	Appleton	16,773	4.0	Fox River
	Milwaukee	373,859	54.88	Lake Michigan
	Superior	40,384	2.3	Shallow wells
Canada	Edmonton, Alb.	30,855	5.25	Saskatchewan River
	Montreal, P. Q.	450,273	55.0	St. Lawrence River
	Montreal, P. Q.	....	30.0	St. Lawrence and Ottawa Rivers
	Ottawa, Ont	73,193	24.0	Ottawa River
Georgia	Commerce	....	0.125	Small stream
	La Grange	....	0.30	Creek
	Milledgeville	....	0.25	Creek
Michigan	Dearborn	....	0.10	River Rouge
Canada, British Columbia	New Westminster	....	9.0	Mountain Lake
Philippine Islands	Manila	....	17.0	Mariquima River

* Number not given.

† Specified only "A. P. H. A. Methods."

	Municipal	Chemist and bacteriologist	Commissioner health
	Private	Superintendent	Directors of company
	Municipal	City chemist	Service director
	Municipal	Filtration expert	Superintendent
	Municipal	Chemist in charge	City manager
	Municipal	Chemist in charge	Superintendent
	Municipal	Chemist in charge	Commissioner division water
	Municipal	City and state bacteriologist	City health officer
	Municipal	City chemist and bacteriologist	Council
	Municipal	Superintendent filtration	Commissioners
	Private	City chemist and bacteriologist	Company
onongahela Rivers	Municipal	Chemical engineer	Superintendent department pub
ill Rivers	Municipal	Two chemists in charge laboratories	Chief bureau of water
	Municipal	Chemist	Chief engineer
	Private	Bacteriologist and chemist	General superintendent
	Municipal	Bacteriologist	City engineer
	Private	Superintendent pump and filter plant	Vice president of company
	Municipal	....	Superintendent water departmen
	Municipal	Operator	Consulting biologist
	Municipal	City bacteriologist and chemist	City health officer
....	Municipal	Superintendent water purification	Commissioner of water
	Municipal	Superintendent filtration	Commissioner water and sewerag
	Municipal	Health officer and chemist	Council and board of health
	Municipal	Director settling basins and laboratories	Superintendent
....	Municipal	City chemist	Commissioner public utilities
	Municipal	Superintendent filtration	City commissioners
	Municipal	Water works chemist	Superintendent
	Private	Assistant engineer	General superintendent
	Municipal	Head operator	Superintendent
	Municipal	Chemist	Engineer superintendent
awa Rivers	Private	Sanitary engineer	General manager
	Municipal	City bacteriologist and chemist	Board of health
	Municipal	Superintendent	City water commission
	Municipal	City engineer	....
	Private	Engineer	Superintendent
	Private	Chemist	....
	Municipal	....	....
	Municipal	Bureau of science	....

ssioner health	1	....	1	....	Agar 24 hours	Agar 48 hours, 2(
rs of company	....	....	....	....	Agar —	Gelatine —
director	....	....	....	No	....	Agar, room temp
tendent	....	....	....	No	Agar —	Gelatine
nager	....	....	....	Yes	....	Agar 48 hours, 2(
endent	....	....	....	Yes	L. lactose and plain agar 24 hours	Agar 48 hours, 2(
sioner division water	3	....	....	Yes	Agar 24 hours	Gelatine 48 hour
lth officer	....	1	....	No	....	Agar 48 hours
	....	....	....	No	Agar 48 hours	Agar 48 hours
sioners	....	....	1	No	Agar 72 hours	Gelatine 72 hour
y	....	....	....	....	....	Gelatine 48 hour
endent department public safety	2	....	1	No	L. lactose agar 24 and 48 hours	Gelatine 48 and
reau of water	*	*	*	Yes	Agar 24 hours	Gelatine 48 hour
gineer	....	....	....	No	....	Gelatine 48 hour
superintendent	....	....	....	No	Agar —	Agar 20°
ineer	....	....	....	No	Agar 24 hours	....
sident of company	....	....	1	....	Agar 24 hours	....
endent water department	....	....	....	No	Agar 24 hours	Agar 20°
ng biologist	....	....	....	No	Agar —	....
th officer	....	1	1	Yes	†	....
ioner of water	1	....	....	No	L. lactose and plain agar occasionally	Gelatine 48 hour
ioner water and sewerage	....	....	....	No	Agar 24 hours	....
nd board of health	1	....	....	....	Agar —	....
ndent	....	....	1	No	Agar —	....
ioner public utilities	2	....	....	Yes	†	....
missioners	....	....	....	No	L. lactose agar 24 hours	Agar 48 hours, 20
ndent	....	....	....	Yes	Agar 48 hours	Gelatine 48 hour
uperintendent	....	....	1	....	Agar 24 and 48 hours	Gelatine 96 hour perature
ndent	....	....	....	No	....	Agar 48 hours
superintendent	1	....	....	No	....	Agar 96 hours, 2(
manager	1	....	....	....	Agar 24 hours	Agar 48 hours, 2(
health	....	....	2	No	Agar 24 hours	Agar 72 hours, 2(
r commission	....	....	....	No	Agar 24 hours	....
....	....	....	....	....	....	....
ndent	....	....	....	....	....	Agar 48 hours, 2(
....	....	....	1	No	†	†
....	....	....	....	....	....	Count 48 hours
....	....	....	....	Philippine civil service	Agar 24 hours	....

			cite		
	Agar 48 hours, 20°	Lactose broth	5 per cent gas; endo; Lactose broth; 5 per cent gas	No	Hardı
	Gelatine —	Lactose broth	....	No	Alkali
......	Agar, room temperature	Dextrose broth Lactose bile	Gas in bile and broth, gelatine, nitrate, indol	No	No
	Gelatine	....	Gas in 48 hours	No	Alkali
......	Agar 48 hours, 20°	Lactose bile	Gas	No	Alkali
ɔlain	Agar 48 hours, 20°	Lactose bile	Gas; acid colonies; gas; indol	No	Alkali
	Gelatine 48 hours, 20°	Lactose broth	Gas; indol; lactose broth; gelatine	No	Alkali chlc
.....	Agar 48 hours	Lactose bile	Gas; acid and gas in L. lactose agar	No	No
	Agar 48 hours	Lactose bile	25 per cent gas; Conradi-Drigalski	No	Comp
	Gelatine 72 hours, 20°	Lactose broth	Gas; L. lactose agar; indol; gelatine; sugars	Occasionally	Alkali
.....	Gelatine 48 hours, 20°	Lactose bile	5 per cent gas	....	Hardı
24	Gelatine 48 and 72 hours, 20°	Glucose broth Lactose broth	15 per cent gas in either	No	Alkali
	Gelatine 48 hours	....	Fermentation lactose and dextrose	Yes	....
.....	Gelatine 48 hours, 20°	....	"Presumptive"	Yes	Sanitε
	Agar 20°	Lactose bile	Gas; L. lactose agar	Yes	Alkali
	....	....	Gas; plate; fermentation tube; indol; gelatine stab	Yes	Weekl
	....	Lactose broth	Gas; L. lactose agar	Yes	Alkali
	Agar 20°	Lactose bile	Gas	No	Alkali
	....	Lactose bile	Gas	Yes	No
	....	....	†	No	Sanitε
ɔlain y	Gelatine 48 hours, 20°	Lactose bile	†	No	Alkali
	....	Lactose bile	Gas 20–70 per cent "confirm occasionally"	No	Alkal
	....	Lactose broth	U. S. P. H. method	Yes	Alkali
	....	Lactose broth	Gas	No	Alkali
	....	....	†	No	Sanit
24	Agar 48 hours, 20°	Lactose broth	....	In summer	Alkali
	Gelatine 48 hours, 20°	....	5 per cent gas	No	....
ɔurs	Gelatine 96 hours, room temperature	Lactose broth	Gas; L. lactose plate; broth; morphology	No	Iron
.....	Agar 48 hours	....	....	....	No
.....	Agar 96 hours, 20°	Lactose bile Dextrose broth	90 per cent bile fermentations	No	Alkal
	Agar 48 hours, 20°	Lactose bile	Gas	No	Alkal
	Agar 72 hours, 20°	Lactose bile	Gas; neutral red bile salt agar; lactose fermentation; non spore former	Yes	Alkal tarү
	....	....	Presumptive	....	Alkal
.....	....	Lactose bile	....	....	Free
.....	Agar 48 hours, 20°C.	....	50 per cent gas in 48 hours	No	Alkal
	†	†	†	....	Alkal
.....	Count 48 hours	....	....	No	No
	....	Lactose	Acid and gas in L. lactose agar	No	Mine

No	Hardness, alkalinity, sanitary examinations	Turbidity, color, odor	....
No	Alkalinity, free chlorine, Fe	Turbidity, color	1915
No	No	....	1911
No	Alkalinity, hardness, Fe, etc.	Turbidity, col r, temperature	....
No	Alkalinity; occasionally Fe, chlorine, incrustants	Turbidity, color, temperature	1909
No	Alkalinity, incrustants, CO_2, $FeSO_4$, $Al_2(SO_4)_3$ occasionally	Turbidity, color	1915
No	Alkalinity, suspended matter, hardness, oxygen consumed, chlorine, Ca, Mg	Turbidity, color, odor, taste, temperature	1910
No	No	No	....
No	Complete once month	No	1914
Occasionally	Alkalinity	Turbidity, temperature	1911
....	Hardness, Sanitary examinations	Turbidity, color, odor	1906
No	Alkalinity, hardness, three to twelve times daily	Turbidity, color	1909
Yes	....	Turbidity, color	....
Yes	Sanitary	Turbidity	1910
Yes	Alkalinity, occasional sanitary examinations, Fe., alum	Tu:bidity, color, odor, sediment	1910
Yes	Weekly sanitary (at sewage station)	Color	1905
Yes	Alkalinity, chlorine, hardness	Odor	1905
No	Alkalinity	Turbidity	1906
Yes	No	No	1915
No	Sanitary monthly	Turbidity	1914
No	Alkalinity, hardness, solids	Turbidity	1914
No	Alkalinity twelve times daily; hardness daily	Turbidity, color, odor, taste	1912
Yes	Alkalinity, dissolved oxygen	Turbidity, color, odor	....
No	Alkalinity	Turbidity, color	1910
No	Sanitary examinations	....	1910
In summer	Alkalinity	Turbidity, color, odor	....
No	....	....	1913
No	Iron	Color, temperature	1906
....	No	....	1912
No	Alkalinity	Turbidity, color	1910
No	Alkalinity	Turbidity, color	....
Yes	Alkalinity, electrical conductivity, Fe, CO_2, hardness, sanitary	Turbidity, color	....
....	Alkalinity and CO_2	....	1915
....	Free alum and chlorine	....	1915
No	Alkalinity	Turbidity	1911
....	Alkalinity, hardness, incrustants	Color, turbidity	1915
No	No	No	....
No	Mineral and sanitary	Temperature, turbidity, color	....

or	....	General city work	"Free of B. coli in 10 cc. and pollution of any kind"
	1915	No	'Negative B. coli in 1 and 10 cc. with not over 50 bacteria per cubic centimeter at 20°C"
....	1911	Milk	"Free from B. coli"
nperature	....	No	"Less than 50 bacteria; free from gas formers in 10 cc."
nperature	1909	Oil, coal, chemicals	"Less than 50 bacteria per cubic centimeter; no B. coli; free from turbidity; color less than 10"
	1915	Supplies	"No free CO_2; most of time 8 or 9 p.p.m. bicarbonate alkalinity, sometimes almost caustic"
odor, taste,	1910	Coal, filter chemicals	"Four parts monocarbonate alkalinity with iron and lime; three parts free CO_2 with alum treatment"
	....	General work	....
	1914	General city work	"No B. coli in 100 cc.
ure	1911	Coal supplies	"A sterile water with no turbidity and the color below 5 p.p.m."
or	1906	General city work	"Less than 50"
	1909	Chemicals, etc.	"Turbidity 0; color not more than trace; hardness below 80; no presumptive B. coli in 10 cc."
	....	....	"Free from B. coli in 1 and 10 cc."
	1910	Materials of construction	....
or, sediment	1910	Coal, chemicals	"Bacteria maximum 10; color 10; turbidity 0; alkaliniy 6-7 p.p.m."
	1905	No	....
	1905	No	"Color 15 p.p.m.; alkalinity 20 p.p.m.; hardness below 50 p.p.m."
	1906	No	"Count below 25 and removal of all gas-forming organisms presumptive for B. coli"
	1915	No	"10 colonies; B. coli absent in 10 cc."
	1914	General city work	"Bacteria under 50; no B. coli"
	1914	Sewage	....
or, taste	1912	Paving materials	U. S. Treasury Department
or	....	General city work	U. S. Treasury Department
	1910	No	"Total count 10 and under; B. coli negative in 20 cc. and turbidity under 4; color under 9"
....	1910	General city work	....
or	....	Milk	"Reduction 97 per cent; total absence of B. coli in 10 cc."
....	1913	Coal, etc.	U. S. Treasury Department
	1906	Sand supplies	"Fe less than 0.3 p.p.m." (primarily for Fe removal)
....	1912	Oil, coal	"As clear and pure as possible"
	1910	Coal, sand, etc.	"Total count less than 20 per cubic centimeter"
	....	Miscellaneous	"99.9 per cent"
	....	Gas, city work	"Coli under 2 per 100 cc."
....	1915	No	"Absolutely clear and as free of all bacteria as possible"
....	1915	No	"Standard of the American Public Health Association"
	1911	No	"High"
	1915	No	"As near zero in all forms of bacteria as possible"
	....	Milk	....
dity, color	....	Much varied	"Improve as much as possible."

STATE	CITY	AVERAGE DAILY PUMPAGE	SOURCE SUPPLY	W
		M. G. D.		
California	Los Angeles	75.0	Aqueduct and river	U. S. T. D.
	Pasadena	5.8	Ground and surface	Total bacteria less
Colorado	Colorado Springs	6.1	Mountain streams and reservoir	48 hours test unde
	Denver	52.0	Lake Cheesman and infiltration	U. S. T. D.
Connecticut	Hartford	11.1	Six reservoirs	Colon negative
District of Columbia	Washington	59.9	Potomac River	As high as possibl
Georgia	Atlanta	18.1	Chattahoochee River	Under 15 bacteria
	Columbus	2.3	Chattahoochee River	As low as possible
	Commerce	0.125	Small stream	Absolutely clear a
	Le Grange	0.3	Creek	Standard of Amer
	Millidgeville	0.25	Creek	High
Illinois	Cairo	4.25	Ohio River	U. S. T. D.
	Chicago	700.0	Lake Michigan	Free of colon in 1(
	Danville	5.37	North Fork Vermillion River	U. S. T. D.
	Decatur	3.93	Sangamon River	U. S. T. D.
	Elgin	1.50	Five wells, 42-2000	....
	Evanston	8.50	Lake Michigan	Very few bacteri alum, free chlori
	Moline	4.00	Mississippi River	Bacteria, 0; gas a 15; turbidity, 0
	Quincy	2.00	Mississippi River	Agar count below
	Streator	....	Vermillion River	Below 50 bacteria
Indiana	Evansville	9 0	Ohio River	U. S. T. D.
	Fort Wayne	6.0	Deep wells	....
	Indianapolis	24.31	Surface and deep wells	U. S. T. D.
	Terre Haute	5.0	Wabash River	Bright and clear
	Valparaiso	0.8	Chain of small lakes	U. S. T. D.
Iowa	Cedar Rapids	3.0	Cedar River and 1500 feet wells	U. S. T. D.
	Council Bluffs	3.25	Missouri River	Less than 50 bac gas formers
	Davenport	4.14	Mississippi River	As nearly sterile a
	Des Moines	6.9	Infiltration gallery, Racoon Valley	75 bacteria per cul
Kansas	Atchison	1.2	Missouri River	....
Kentucky	Louisville	26.0	Ohio River	Less than 100 bac

WORKING STANDARD	ABRUPT CHANGES IN RAW WATER	NO. FILTER UNITS	TYPE FILTERS	RATE OF OPE[R]
U. S. T. D.	Seldom	None		
Total bacteria less than 20 per cubic centimeter	Part	None		
48 hours test under 10 per cubic centimeter	At heavy rains	None		
U. S. T. D.	Yes		Slow and rapid sand	
Colon negative	Moderate	None		
As high as possible	Yes	29	Slow sand	2.5 m.g.a.d.
Under 15 bacteria per cubic centimeter	Yes	48	36 N. Y. C. Jewell, ½ m.g.d. 12 Hyatt vertical, ¾ m.g.d.	21–35 m.g.a.d.
As low as possible in bacteria and B. coli	Very	4	Rapid sand	1 m.g.d. per unit
Absolutely clear and as free from bacteria as possible	Local rains	1	Rectangular concrete	½ normal
Standard of American Public Health Association	Yes	3	American Water Softener Co.	346 gallons per m
High	Yes	2	Pressure	500,000 gallons
U. S. T. D.	Yes	6	N. Y. C. Jewell, tub	Overloaded
Free of colon in 10 cc.				
U. S. T. D.	Yes	8	Concrete Jewell, 7.5 m.g.	125 m.g.a.d.
U. S. T. D.	Yes	6	N. Y. C. J.	1.5 m.g.a.d.
	No		N. Y.	
Very few bacteria. No gas. No color, turbidity, alum, free chlorine	Yes	6	2 m.g. gravity mechanical	100–125 m.g.a. d.
Bacteria, 0; gas absent in 1 cc. and 4/5 10 cc.; color 15; turbidity, 0	Yes	5	Concrete gravity	125 m.g.a.d.
Agar count below 50; Coli absent in 10 cc.	Yes	6	N. Y. C. J., 1 m.g. units	120 m.g.a.d.
Below 50 bacteria in 1 cc., negative gas tests	Very	16	American pressure	1½ feet per minut
U. S. T. D.	Yes	12	Gravity	125 m.g.a. d.
	No			
U. S. T. D.	Yes	6	Slow sand	4–6 m.g.a.d.
Bright and clear	Yes	22	Jewell pressure	00 m.g.a.d.
U. S. T. D.	Seldom	3	Gravity	00 m.g.a.d.
U. S. T. D.	Yes	14	12 Tub Jewell; 2 N. Y. C. J.	75 m.g.a.d.
Less than 50 bacteria per cubic centimeters. No gas formers		None		
As nearly sterile as possible	Yes	12	Pressure	1 gal sq. ft. min.
75 bacteria per cubic centimeter; no gas formers	Yes.	None		
	Yes			
Less than 100 bacteria; no B. coli in 1 and 10 cc.	Yes	18	Gravity	130 m.g.a.d.

TABLE 2

American Water Works Laboratorie

	RATE OF OPERATION	HOW OFTEN CLEANED	MANNER OF CLEANING	POINT OF CHLORINATION	CONTROL OF DOSAGE OF CHEMICALS	PERIOD OF SEDIMENTATION	
......	....	....	....	Intake	Manual	....	24
......	....	....	....	Intake	Manual	....	10
......	....	....	....	....	....	....	...
	....	....	....	After filtration	Automatic	....	...
......	....	....	....	Where enters main	....	....	...
	2.5 m.g.a.d.	Av. 71 days	Scrape and rake	....	....	4 days	4
;.d.	21-35 m.g.a.d.	30 hrs	Mechanical	....	Manual	6-10 hours	2
.l.							
	1 m.g.d. per unit	24 hours	Air and water	....	Orifice tanks	6 hours	2½
	½ normal	24-30 hours	Air and water	....	Automatic	3 hours	...
r Co.	346 gallons per minute	When needed	Air and water	Effluent from filters	....	6 hours	15
	500,000 gallons	48 hours	Back pressure	Between settling basin and main pump	....	6 hours	N
	Overloaded	4-24 hours	Air and water	Effluent from filters	Manual	3 hours	1 :
......	....	....	....	....	....	....	...
	125 m.g.a.d.	6-24 hours	Air and water	Effluent from filters	....	1 hour	4-
	1.5 m.g.a.d.	24 hours	Water	Effluent from filters	....	4-6 hours	18
	....	....	....	....		....	...
al	100-125 m.g.a. d.	8-48 hours	Air and water	Effluent from filters	....	2 hours	4]
	125 m.g.a.d.	12-40 hours	Air and water	Effluent from filters	....	2-3 hours	5]
	120 m.g.a.d.	4-20 hours	Air and water	Suction H. S. pump	....	4.5 hours	N
	1½ feet per minute	24 hours	Water	Effluent from filters	....	5.8 hours	1.:
	125 m.g.a. d.	24 hours	Air and water	Coagulated water	Manual	5 hours	3]
......	....	....	....	....	....	....	...
	4-6 m.g.a.d.	25-30 days	Scrape, washing	Effluent from filters	Manual	48 hours	12
	00 m.g.a.d.	24 hours	Water	....	....	4 hours	N
	00 m.g.a.d.	24-36 hours	Air and water	Clear well	....	2½-3 hours	½-
C. J.	75 m.g.a.d.	24 hours	Air and water	Effluent from filters	....	½-1 hour	3]
......	....	....	....	After sedimentation	....	5-6 days	N
	1 gal sq. ft. min.	24 hours	Air and water	After coagulation	....	24 hours	...
......	....	....	....	Effluent gallery	Automatic	....	...
......	....	....	....	....	Automatic	1 week	1
	130 m.g.a.d.	20 hours	Water	After coagulation	Manual	4.8 or 12 hours	24

TABLE 2

Works Laboratories. (Plant Data)

TROL OSAGE EMICALS	PERIOD OF SEDIMENTATION	STORAGE OF TREATED WATER	CONSUMPTION DETERMINED BY	COLOR		TURBIDITY		IRON		ALKALIN	
				Raw	Ttd.	Raw	Ttd.	Raw	Ttd.	Raw	
ıal	....	24 hours	....	15	....	5	....	<1	....	130	..
ıal	....	10 days	Venturi meter	Clear	....	No	....	2–6 3	....	....	..
....	....	....	....	No	....	....	....	....	....	Trace	..
matic	....	....	Checked	2–50 15	0	2–400 27	0	0.2	0	90	
....	....	....	....	28–48 36	20–36 28	1–8 4	Same	....	....	24–38	
....	4 days	4 hours	Venturi	Slight	No	238	0	....	....	58	
ıal	6–10 hours	2 weeks	Venturi	....	No	24–600	0	....	....	8–15	
ıc tanks	6 hours	2½ m.g. basin	....	Red brown	Clear	10–3000	....	....	....	0–17	..
matic	3 hours	....	Revolution counter	....	5	....	0	....	0	12	
....	6 hours	15 hours	Venturi	Red	0	50–4000	0	....	....	2–30	..
....	6 hours	No	Manometer	....	....	8–3000	0	....	....	30–50	1
ıal	3 hours	1 hour	Revolution counter	10–30	0–5	100–2000	15–35	Very low	0	40–110	1
....	....	....	....	0	0	0.120	....	0	0	....	..
....	1 hour	4–6 hours	Pitometer	20–250	0–30	25–2000	0	0.39	0	50–340 250	..
....	4–6 hours	18 hours	Venturi on L. S.	0–20 12	0.10 3.7	10–285 139	0	....	....	188–274 237	18
....	....	....	Revolution counter	5–60	....	10–12	....	0.5–1	....	300	..
....	2 hours	4 hours	Recording Venturi	6	0	13	0	....	....	119	
....	2–3 hours	5 hours	Venturi	20–100	5	0–6000	0	Maximum 2	....	50–170	20
....	4.5 hours	None	Venturi on both H. S. and L. S.	25–50 36.5	5–10 5.6	10–1500 110	0	....	....	82–186 134	4
....	5.8 hours	1.2 hours	Revolution counter	10–120	0.1–20	10–3000	0	....	....	10–290	..
ıal	5 hours	3 hours	Venturi	8–12	5	15–4000	0	Traces	....	35–115	..
....	....	....	....	Clear	....	Slight at times	....	....	....	30–35	..
ıal	48 hours	12 hours	Venturi	10–480 53	5–35 12	3–338 39	0–3 0	0.9–3 1.9	0.1–0.7 0.26	188–259 237	8
....	4 hours	None	Tachometer	34	14	138	0	Small	....	195	
....	2½–3 hours	½–1 hour	Revolution counter	36–58	20–45	....	....	No	Trace	260–580 300	140
....	½–1 hour	3 hours (maximum)	Revolution counter	0–100	0–10	0–3000 90	0	0.3	0.3	50–250 200	20
....	5–6 days	None	Pitometer	0–80 15	0–60 10	50–12000 2500	0–50 4	0.2–0.5	....	....	100
....	24 hours	....	Revolution counter	30–80	3–30	3–3000	0–15	....	....	71–174	32
natic	....	....	Venturi	Trace	None	15	3	0.6	0.6	243	
natic	1 week	1 week	Revolution counter	....	....	400+	5–15	....	....	....	..
al	4.8 or 12 hours	24 hours	Revolution counter	0	0	Maximum 600 Average 400	0	2–20 7	0.1–2.0 1	20–80 55	15

IRON		ALKALINITY		BACTERIA AT 37°C.		BACTERIA AT 20°C.		B. COLI	
r	Ttd.	Raw	Tid.	Raw	Treated	Raw	Ttd.	Raw	
	....	130	....	125	....	....	....	25 per cent 10 cc. samples	....
	....	....	....	0–200	0–10	5–800	0–15	None	None
....	....	Trace	....	17*	....	100*	....	1 per cent 1 cc.	....
	0	90	85	1–280	0–17	1–5400	21–69	....	....
....	....	24–38	Same	....	....	617	19	15 per cent 10 cc.	Absen
....	....	58	55.4	....	....	5540	15	575.4 per 100 cc.	
....	....	8–15	5–10	239	11	....	....	....	....
....	....	0–17	....	Max. 13,000	12	....	....	All times	1–2 pe
....	0	12	6	285	3	....	....	....	Negat
....	....	2–30	....	50–200	0–2	....	....	Varies	None
....	....	30–50	15–30	....	....	2000	10	....	....
ow	0	40–110	17–85	250–1500	5–40	....	....	Always present	97–98 ı
	0	....	....	11	6	Agar, 165 Gel. 210	Agar 55 Gel. 77	1.8 per cent in 1 cc.; 17.2 per cent in 10 cc.	0.2 pe per (
	0	50–340 250	....	2230	0–15	....	....	....	12 per 0.15 ı firm
....	....	188–274	180–270	52–7300	0–30	Gel. 6–75,000	0–340	Always present	Absent
		237	224	1075	7	7203	49		
l	....	300	....	1–10	....	Gel. 2–3	....	Occasionally	....
....	....	119	112	40	0.3	241	0.59	1.21	
ım	....	50–170	20–160	500–200,000	0–500	....	....	....	....
....	....	82–186	42–154	34–50,500	0–585	....	....	22.9 per cubic centimeter	0.081 p
		134	109	2085	10.9				
....	....	10–290	....	100–300,000	0–110	....	....	....	....
s	....	35–115	....	1250	50	Gel. 5000	45	78.1 per cent of 1/10 cc.	5.8 per 17.3 pe
....	....	30–35	....	1–3	....	....	....	None	....
3	0.1–0.7	188–259	81–258	255–3500	0–20	180–15,000	0–150	1173 per 100 cc.	0.64 pe
	0.26	237	238		5	1722	9		
l	....	195	185	....	....	Gel. 3200	38	....	....
	Trace	260–580	140–460	50–640	0–58	Gel. 80–1800	0–140	Present in summer	5 per c
		300	220	220	18	360	39		20 per
	0.3	50–250 200	20–240 190	100–50,000	0–100	Gel. 1000–1,000,000	0–1000	1–1000 per cubic centimeter	Less tl
5	....	....	100–250 150	....	....	5000–150,000 24,000	5–200 48	....	....
....	....	71–174	32–165	....	....	Gel. 5890	18	....	....
	0.6	243	243	80	7	535	43	44.5 per cent of 5 cc.	3 per c 7.4 pe 7.4 per
....	....	....	....	....	....	....	....	....	....
	0.1–2.0 1	20–80 55	15–70 45	L. L. A. 2000	5	Gel. 25,000	50	100 per cubic centimeter	1 per 3

B. COLI		CHEMICALS, POUNDS PER MILLION GALLONS							
Raw	Ttd.	Aluminium sulphate	Copper sulphate	Iron sulphate	Lime CaO	Hydrated lime	Calcium hypo-chlorite	Liquid chlorine	Soda ash
t 10 cc. samples	...	...	...	...	...	...	...	2.0–2.5	...
	None	...	...	...	...	...	...	1.7	...
1 cc.	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	+	...
10 cc.	Absent 10 cc.	...	...	...	...	...	...	5	...
0 cc.	0.3	40	...	...	4	...	...	...	...
...	...	51	...	...	...	...	...	...	...
	1–2 per cent plus	71–355	...	...	...	35–130 when used	...	...	...
...	Negative	66	...	...	...	...	...	...	...
	None	100–213	...	...	...	...	...	2	71–284
...	...	200–800	...	...	...	...	6–10	...	...
sent	97–98 per cent absent	71–568	...	...	Rarely	Rarely	...	2.6–3.3	...
t in 1 cc.; 17.2 in 10 cc.	0.2 per cent in 1 cc.; 10.8 per cent in 10 cc.	...	...	...	...	...	...	0.8–1.6	...
...	12 per cent 10 cc. gas 0.15 per cent cc. confirmed	...	...	15–850 285	23–690 360	...	...	1.0	...
sent	Absent in 10 cc.	227*	...	...	...	...	4–8	...	...
y	...	...	...	...	...	...	...	...	...
1.21	0	85	...	...	...	...	3	...	...
...	...	710–1275	8.3 when algae present	...	725 for few days	...	...	4.5–6.5	...
ic centimeter	0.081 per cubic centimeter	355–1065 470	...	...	...	...	...	1.7–5.8	...
...	...	0–800		...	0–800	...	8–16	1.5–6	...
t of 1/10 cc.	5.8 per cent of 1 cc. 17.3 per cent of 10 cc.	...	...	350	...	170	7	...	...
	...	...	...	...	...	...	...	...	...
0 cc.	0.64 per 100 cc.	Variable	...	...	...	50–750	...	1–2.5	...
...	...	280	...	...	...	...	8.5	...	...
summer	5 per cent of 1 cc. 20 per cent of 10 cc.	185	...	...	...	...	...	2.73	...
cubic centi-	Less than one	21–285	8.3	...		...	10–15	2.1–4.2	...
...	...	140–425	8.3	...	...	71–210	...	1.7–2.5	...
...	...	210	In summer	...	...	125	...	2–1	...
...	...	521	...	...	...	...	...	4.5	...
t of 5 cc.	3 per cent of 1 cc. 7.4 per cent of 5 cc. 7.4 per cent of 10 cc.	...	...	...	...	...	...	3.5	...
...	...	152	...	...	...	142	10–12	...	...
bic centimeter	1 per 300 cc.	142	...	...	...	...	7.5	1.8	...
		11–570		...	...	...	...	...	...

	Des Moines	6.9	Infiltration gallery, Racoon Valley	75 bacteria per cul
Kansas	Atchison	1.2	Missouri River	....
Kentucky	Louisville	26.0	Ohio River	Less than 100 bac
Louisiana	Morgan City	0.25	Atchafaloya River	No B. coli; 98 to
	New Orleans	30.0	Mississippi River	U. S. T. D.
Massachusetts	Brockton	2.9	Silver Lake	Do not treat
	Lowell	6.0	2½ feet driven wells	Remove Fe and M
Michigan	Bay City	7.0	Saginaw River and Bay	....
	Dearborn	0.10	River Rouge	As near 0 bacteria
	Grand Rapids	12.35	Grand River	Alkalinity and tot
Minnesota	Minneapolis	30.0	Mississippi River	Below 10 bacteria sent in 20 cc.
Missouri	St. Louis	98.0	Mississippi River	Agar count below
	Springfield	4.0	Springs and deep wells	Bacteria as low as
Nebraska	Omaha	20.0	Missouri River	Count less than 10
New Jersey	Paterson, etc.	37.0	Passaic River	Color 10 or less; ba
	Trenton	17.5	Delaware River	Bacteria reduction per cent
New York	Albany	20.0	Hudson River	Gelatin count und Less than 25 per ce
	Auburn	6.5	Owasco Lake	Gelatin 100; color
	Kingston	4.5	Sawkill Creek	Gelatin 100; color
	Mt. Vernon	2.5	River	Below 50 bacteria
	Newburgh	5.13	Lake	Free from gas-form
	New York	550.0	Surface and ground supplies	Free from B. coli i
	Niagara	10.5	Niagara River	Free from B. coli i
	Poughkeepsie	2.54	Hudson River	100 per cent
	Schenectady	11.16	Three dug wells	....
	Syracuse	....	Skaneatles Lake	B. coli absent
	Utica	12.5	West Canada Creek	....
	Watertown	5.5	Black River	Color below 10; cou
	Yonkers	9.0	Nepperhar River, Grassy Sprain Creek	Bacteria 15 to 25 in 10 cc.
North Carolina	Wilmington	3.0	Cape Fear River	B. coli absent in 10
Ohio	Akron	20.0	Cuyahoga River	Free from B. coli < 100
	Alliance	6.0	Mahoning River	Turbidity 0; no B.
	Bucyrus	1.5	Reservoir	....
	Cincinnati	50.0+	Ohio River	....
	Cleveland	96.0	Lake Erie	As low as possibl bad taste and odc
	Columbus	20.0	Scioto River	B. coli absent in 50
	Dayton	12.9	Deep wells	B. coli absent in 10
	Dennison	2.0	Big Stillwater Creek	B. coli absent in 10
	Lima	3.5	Ottawa River	Free from B. coli

75 bacteria per cubic centimeter; no gas formers	Yes.	None	...	...
...	Yes	...	...	...
Less than 100 bacteria; no B. coli in 1 and 10 cc.	Yes	18	Gravity	130 m.g.a.d.
No B. coli; 98 to 100 per cent bacteria removal	No	2	Rapid sand	8,000 gallons per l
U. S. T. D.	No	10	Rapid sand	40–150 m.g.a.d.
Do not treat	...	...	...	...
Remove Fe and Mn. (plant for that purpose)	No	12	6 Coke prefilters 6 Slow sand	Coke—75 m.g.a.d. Sand—10 m.g.a.d.
...	...	...	...	...
As near 0 bacteria as possible	Yes	4	N. Y. C. J., gravity	½ m.g. each
Alkalinity and total hardness as low as possible	No	10	Rapid sand	2 m.g.a.d.
Below 10 bacteria per cubic centimeter; B. coli absent in 20 cc.	Yes	16	Mechanical concrete	72 m.g.a.d.
Agar count below 50; B. coli absent in 50 cc.	Yes	40	Rapid sand	60–100 m.g.a.d. 85 m.g.a.d.
Bacteria as low as possible; no B. coli	Yes	6	Gravity	2 gal. sq. ft. min.
Count less than 100; no B. coli in 1 cc.	No	None	...	...
Color 10 or less; bacteria 5	No	32	N. Y. C. J.	120–200 m.g.d.
Bacteria reduction 99.9 per cent; B. coli negative 90 per cent	Yes	16	Rapid sand	1.5–2 gal. sq. ft. n
Gelatin count under 50; agar count under 5 Less than 25 per cent B. coli tests positive	Yes	16 8	Rapid sand Slow sand	80 m.g.a.d. 3.5 m.g.a.d.
Gelatin 100; color 10	No	...	...	...
Gelatin 100; color 10; turbidity 0.	Yes	12	N. Y. C. J. pressure	...
Below 50 bacteria per cubic centimeter	Yes	4	American Pipe and Construction Co.	100 per cent capac
Free from gas-formers in 10 cc.	Yes	...	...	...
Free from B. coli in 10 cc.	...	...	...	...
Free from B. coli in 10 cc.	...	16	Rapid	¾–1¼ m.g.d.
100 per cent	Yes	4	Slow sand	2¼ m.g.a.d.
...	...	...	...	...
B. coli absent	...	...	...	...
...	Yes	...	...	...
Color below 10; count 20	Yes	8	Rapid sand	120 m.g.a.d.
Bacteria 15 to 25 per cubic centimeter; no. B. coli in 10 cc.	Yes	2 4	Open slow sand Closed slow sand	3–5 m.g.a.d.
B. coli absent in 10 cc.	Yes	8	Mechanical	100–135 m.g.a.d.
Free from B. coli in 1 cc.; usually in 10. 20° Count < 100	No	10	...	125 m.g.a.d.
Turbidity 0; no B. coli in 1 cc.	Very	6	...	125 m.g.a.d.
...	Yes	4	2 Pittsburgh mechanical 2 tub and rake	Nearly full capacit
...	Yes	28	4 m.g. mechanical	125 m.g.a.d.
As low as possible in bacteria without producing bad taste and odor of chlorine	No	...	Rapid sand	...
B. coli absent in 50 cc.; total count below 20	Yes	10	Mechanical	110 m.g.a.d.
B. coli absent in 10 cc.	No	...	...	...
B. coli absent in 10 cc.; not over 20 bacteria at 20°	Yes	4	16 foot Jewell	125 m.g.a.d.
Free from B. coli	Yes	...	Mechanical	...

...	...	...	...	Effluent gallery	Automatic	...	..
...	...	...	...	...	Automatic	1 week	1
	130 m.g.a.d.	20 hours	Water	After coagulation	Manual	4.8 or 12 hours	24
	8,000 gallons per hour	24–48 hours	Air and water	...	...	6 hours	6
	40–150 m.g.a.d.	2–12 days; 106 hours	Water	Effluent from filters	Automatic	12 hours	N
...	...	...	...	...	...	...	...
	Coke—75 m.g.a.d. Sand—10 m.g.a.d.	Coke weekly Sand 40 days	Water Scraping	None used	...	2 hours	4
...	...	...	...	...	...	...	...
	½ m.g. each	...	Air and water	Filter surface	...	2½–24 hours	2½
	2 m.g.a.d.	21 hours	High velocity water	Before filters	Automatic	2–4 hours	6–
	72 m.g.a.d.	24 hours	Water	After filtration	Automatic	3–6 hours	36
	60–100 m.g.a.d. 85 m.g.a.d.	3–168 hours 48 hours	Water	After filtration	For alum Nor for iron and lime	30–40 hours 5–6 hours	1
	2 gal. sq. ft. min.	24 hours	Air and water	Part in raw; part in filtered	Automatic	3 hours	2
...	...	...	...	Suction well	Manual	48–72 hours	48
	120–200 m.g.d.	11.50 hours	Air and water	Effluent from filters	...	4.14 hours	10
	1.5–2 gal. sq. ft. min.	12–100 hours	Air and water	Effluent	...	2½–5 hours	1
	80 m.g.a.d. 3.5 m.g.a.d.	24 hours 1 month	Water, scraping	Effluent	...	12–14 hours	1
...	...	...	...	Suction well	Automatic	...	...
	...	24 hours	Water	Effluent of filters	Automatic	None	N
truc-	100 per cent capacity	24 hours	Water	Intake	Automatic	5 hours	N
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	V
	¾–1¼ m.g.d. 2¼ m.g.a.d.	24 hours 93 days	Air and water Ejector system	Effluent from filters Raw and filtered	... ...	4 hours 20 hours	2 3–
...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...
...	...	...	...	At Venturi from reservoir	Automatic	...	...
	120 m.g.a.d.	6-48 hours	Water	Effluent from reservoir	...	3 hours	1
	3–5 m.g.a.d.	3–6 weeks	Scraping	Effluent from reservoir	...	...	1
	100–135 m.g.a.d.	17–90 hours	Air and water	Clear well	...	6 hours	...
...	125 m.g.a.d.	...	Water, 21 inch rise	Suction well	...	24 hours	20
...	125 m.g.a.d.	2–54 hours 20 hours	Water, 24 inch rise	Effluent from filters	...	3 hours	20
	Nearly full capacity	24 hours	Air and water	Before filtration	...	6 hours	4
	125 m.g.a.d.	20 hours	High velocity washing	Effluent from filters	...	6–12 hours	6–
	...	...	...	Pump suction	Automatic	3 hours	<
	110 m.g.a.d.	48 hours	Water	As applied to filters	Automatic	18 hours	12
...	...	...	...	...	...	...	...
	125 m.g.a.d.	When needed	Water	Clear well	...	4 hours	N
	...	...	...	Pump suction	Automatic		

	counter									
...	Venturi	Trace	None	15	3	0.6	0.6	243	243	80
week	Revolution counter	...	...	400+	5-15	...	...	...	...	...
hours	Revolution counter	0	0	Maximum 600 Average 400	0	2-20 7	0.1-2.0 1	20-80 55	15-70 45	L. L. A. 200(
hours	Revolution counter	10-100	5-50	70-800	0	...	...	70-130	60-120	2000-70,00(
one	Venturi	8-20 10	3-6 5	60-2400 600	0-3 0	0.3	Trace	53-175 94	25-75 37	400-9500 200
...	...	...	...	...	...	0.05	...	...	...	L. L. A. 2
hours	Venturi	38	0	25	0	2.25 Minimum 1.9	0.2 0.00	23	...	...
...	...	...	...	...	...	...	...	...	...	...
-24 hours	Venturi	41	9	63	0	...	...	212	204	357
8 hours	Venturi	16-68 33	3-23 7	3-126 13	0	Trace	...	103-251 200	32-123 53	80
hours	Venturi	21-84 41	9-27 12	1-150 18	0	0.11-0.66 0.33	0.03-.07 0.05	77-202 153	52-190 134	775
day	Venturi	12-80 35	9-18 11	25-4800 1500	0 0	...	0.005	74-258 142	26-111 52	300-79,000 12,000
hours	Venturi	3-6 3.5	0	0-315 10.8	0	...	...	134-197 165	...	...
hours	Venturi	6-10	0-10	50-1200	0-5	...	...	96-260	80-260	...
days	Venturi	32	9	7	0	0.1	0	18-32 26	20	...
week	Pitometer	10-80	3-15	2-2000.	0-3	...	...	5-40	5-30	...
hour	Venturi	41	23	2.3	0	0.2	0.2	68	66	Neutral bile aga Agar, 975
...	...	...	...	...	...	...	...	...	...	5-50
one	Venturi	5-65 20	0-10 4	1-50 20	0	...	...	8-19 12	7.5-19 11	850
one	Simplex	...	...	10-200	...	...	0.2	15-80	15-60	...
...	...	20	20	0	0	0.05	0.05	32	33	480
ries	Venturi	13-27 18	8-23 14	1-5 2	1-6 2	0-0.5 0.2	0.1-0.2 0.16	19-36 28	28-32 31	3-500 62
hours	...	Trace	Trace	10-2000	...	...	...	101	90	...
5 days	Venturi	25-70 40.6	0-35 9.2	12-600 52.5	0	...	...	30-57 44.3	24-56 37.7	1,001
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	14.1	...	110
day	Venturi	40-140	0-50	2-10	0.6	0.2-0.4	0-0.2	10-35	4.20	...
hour or less	Venturi	22	13	5.2	0	...	...	8	8.7	...
...	...	60-300	0-30	10-1000	0-30	Trace	...	5-9	10	400
m.g. basin	Venturi	33	12	11	0	0.43	0.05	70	58	246
minutes	Revolution counter	20-40 25	3-20 12	5-1100 35	0	0.5-3.5 1.0	0-0.1 0.02	12-210 130	5-205 120	1500 (acid forr 520)
hours	...	Yellow	Clear blue	90	10	...	...	50-80	20-40	...
12 hours	...	5-25 10	3-12 7	3-4000 185	0-tr.	0.01-0.05 0.03	0.01-.10 0.05	22-62 35	33-60 41	...
4 hours	Venturi (raw)	<10	...	15	...	Very low	...	90	...	106
hours	Venturi	29	4	58	0	...	...	170	51	...
...	Venturi and pi-tometer	...	...	0	...	0.15	...	282	...	0-9
one	Venturi	"Mud"	Clearer	50-1900	20-100	...	...	90±	80±	9000
	Revolution	20		20		0.1-1.0	...	100-200	...	...

243	80	7	535	43	44.5 per cent of 5 cc.	3 per cent of 1 cc. 7.4 per cent of 5 cc. 7.4 per cent of 10 cc.	...
......	......	......	......	......	......	......	
-70 45	L. L. A. 2000	5	Gel. 25,000	50	100 per cubic centimeter	1 per 300 cc.	
)-120	2000-70,000	0-400	......	......	Variable	......	
-75 37	400-9500 200	1-120 14	Gel. 500-7500 2900	2-650 38	35 per cent 1 cc.	5 per cent of 10 cc.	...
......	L. L. A. 2	......	......	......	None	......	...
......	......	......	......	......	......	......	...
......	......	......	......	......	......	......	...
204	357	2	1220	5	318 days in 1 cc.	1 day in 1 cc.	
2-123 53	80	3	1340	4	5.700 in 1 cc.	0.00672 in 1 cc.	
2-190 134	775	7	2250	24	15 per cubic centimeter	0.2 per 100 cc.	
3-111 52	300-79,000 12,000	2-135 16	11,000-500,000 81,000	26-1070 170	0-265 31	0.0024-0.0425 0.0166	
......	......	......	Gel. 1436	6	36.42 per cent of 1 cc.	0	
)-260	......	30	Gel. 20,000 Agar, 12,000	60 50	98 per cent of 1 cc.	0	
20	......	......	......	......	65 per cent positive	......	
5-30	......	......	10,000	6	98 per cent of 1 cc.	5 per cent of 10 cc.	
66	Neutral bile agar, 135 Agar, 975	9 3	Gel. 51,525	22	45	0	
......	5-50	......	Gel. 10-80	......	11.3 per cent of 10 cc.	......	...
.5-19 11	850	0-50 8	Gel. 17,500	0-40 10	0/5-5/5, Av. 2/5	0/5	
5-60	......	......	1000	20	Present	Rarely in 10 cc.; never in 1 cc.	
33	480	38	......	......	Present in 1 cc.	Absent in 10 cc.	...
8-32 31	3-500 62	2-480 18	......	......	3 per cent of 1/10 cc.; 11 per cent of 1 cc.; 40 per cent of 10 cc.	2 per cent of 1 cc.; 19 per cent of 10 cc.	...
90	......	......	600-50,000	0-50	75 per cent of 1/10 cc. +	15 per cent 10 cc.	
4-56 37.7	1,001	0-10 3	Gel. 5509	0-14 4	......	0.24 per cent 1 cc.; 1.44 per cent 10 cc.	.
......	......	......	Gel. 3	......	......	Absent	..
						Absent	..
......	......	......	......	......	......	Absent	..
......	110	12	......	......	11.5 per cent	1.5 per cent	..
4.20	......	......	Gel. 200-50,000	0-1500 20	......	......	
8.7	......	......	Gel. 300-31,000	21	91.8 per cent of 1 cc.	......	
10	400	8	1476	19	7 per cubic centimeter	4 per 1000 cc.	
58	246	11	1827	34	Index 1.295	0.009	
-205 120	1500 (acid formers 520)	40 Acid formers rare	5000	80	Always in 1 cc.	33 per cent of 10 cc. Rarely in 1 cc.	
20-40	......	......	......	......	......	......	
33-60	......	......	100-310,000	2-480	0.1-1000	0-1	...
41			13,900	48	21.56 per cubic centimeter	0.07198 per cubic centimeter	
......	106	19	......	......	......	......	...
51	......	......	8027*	24*	44 per cubic centimeter*	0.084 per cubic centimeter	
......	0-9	......	3-7	......	1/13 in 10 cc.	......	...
80±	9000	6000	40,000	27,000	......	......	
......	......	......	720	60	Present	Absent	...

nt of 5 cc.	3 per cent of 1 cc. 7.4 per cent of 5 cc. 7.4 per cent of 10 cc.	...	...	...	...	...	...	...	...
...	...	152	...	...	...	142	10-12	...	...
bic centimeter	1 per 300 cc.	142	...	...	...	...	7.5	1.8	...
	...	11-570	...	...	...	...	...	...	...
1 cc.	5 per cent of 10 cc.	...	...	0-170 62.5	440-1150 770	...	1.76-7.92 4.39	0.83-1.3 1.19	...
	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...
1 cc.	1 day in 1 cc.	253.2	...	...	...	...	...	2.9	...
c.	0.00672 in 1 cc.	132	...	...	1290	...	6	...	...
c centimeter	0.2 per 100 cc.	346	...	...	...	...	...	2.5	...
0-265 31	0.0024-0.0425 0.0166	0-234 85	...	0-355 94	430-862 743	...	...	0-4 1.45	...
ent of 1 cc.	0	61	...	...	...	...	6.4	...	...
of 1 cc.	0	177	...	...	142	...	...	2.5	...
positive	...	155	...	...	...	14.5	...	1.7	8.3
t of 1 cc.	5 per cent of 10 cc.	81-109	...	...	...	...	...	1.7	...
45	0	308	...	...	...	...	...	4.0	...
nt of 10 cc.	...	...	...	...	...	...	...	...	...
r. 2/5	0/5	35-71	2-3	...	...	...	4.7	...	...
	Rarely in 10 cc.; never in 1 cc.	50-100	...	...	...	...	...	2.5-3.5	...
1 cc.	Absent in 10 cc.	...	2.5	...	...	...	...	1.5-3.75	...
cf 1/10 cc.; 11 of 1 cc.; 40 per 0 cc.	2 per cent of 1 cc.; 19 per cent of 10 cc.	...	...	...	...	...	...	...	...
t of 1/10 cc. +	15 per cent 10 cc.	85		...	...	...	4.75	...	...
...	0.24 per cent 1 cc.; 1.44 per cent 10 cc.	...	...	...	...	...	...	...	...
...	Absent	...	...	...	...	...	...	...	...
	Absent	...	...	...	...	...	...	...	...
...	Absent	...	...	...	...	...	...	...	...
nt	1.5 per cent	...	...	...	...	...	...	...	...
...	...	200-450	...	...	...	...	...	1.7-8.3	...
nt of 1 cc.	...	...	...	...	...	...	12-20	2-3	...
c centimeter	4 per 1000 cc.	327	...	...	...	140	...	3.3	...
	0.009	214	...	...	...	...	...	1.89	...
1 cc.	33 per cent of 10 cc.	17-640	...	...	...	...	...	2.5-4.1	...
	Rarely in 1 cc.	157	...	...	...	...	...	3.7	...
...	...	200-800	...	...	...	...	16	...	...
1-1000 ubic centimeter	0-1 0.07198 per cubic centimeter	...	...	106-355 187	64-142 106	...	...	0.8-1.5 1.1	...
...	...	...	...	...	...	...	5-12	...	...
ic centimeter*) cc.	0.084 per cubic centimeter	284	...	...	1206	...	5	...	752
	...	...	...	...	...	...	...	...	...
...	...	0-or 71-284	...	142-568	25	...	8	...	...
	Absent	...	...			...	8	1.8	...

Ohio	Cleveland	96.0	Lake Erie	As low as possibl bad taste and odc
	Columbus	20.0	Scioto River	B. coli absent in 50
	Dayton	12.9	Deep wells	B. coli absent in 10
	Dennison	2.0	Big Stillwater Creek	B. coli absent in 10
	Lima	3.5	Ottawa River	Free from B. coli
	Niles	1.5	Mahoning River	B. coli absent in 10
	Port Clinton	0.56	Lake Erie	Normal carbonate a
	Sandusky	4.5	Sandusky Bay	Less than 50 bacteri
	Steubenville	4.2	Ohio River	No free CO_2; bicarl
	Toledo	21.8	Maumee River	3 parts free CO_2 wh bonate alkalinity
Oregon	Portland	65.0	Bull Run Lake	....
Pennsylvania	Allentown	12.0	Two springs	No B. coli in 100 cc
	Erie	19.0	Lake Erie	Sterile; no turbidity
	Lancaster	7.23	Conestoga Creek	Less than 50
	McKeesport	5.0	Youghiogheny and Monongahela	No B. coli in 10 cc.;
	Philadelphia	300.0	Delaware and Schuylkill Rivers	Free from B. coli in
	Reading	....	Reservoirs and springs	....
Rhode Island	Newport	6.5	Impounded surface	Maxima bacteria 10 bidity 0
	Providence	22.5	Pawtucket river	....
South Carolina	Charleston	6.25	Improved reservoir	Color 15; alkalinity
	Columbia	5.5	Congaree River	Count < 25; remove
South Dakota	Huron	0.5	James River	Count 10; no B. coli
Tennessee	Nashville	13.0	Cumberland River	Bacteria < 50; no B
Texas	Dallas	7.5	....	....
	Ft. Worth	5.0	Trinity River	U. S. T. D.
Virginia	Lynchburg	6.0	Reservoir on Pedlow River	U. S. T. D.
	Richmond	13.35	James River	Total count 10; no B
Washington	Spokane	19.45	Ground	....
Wisconsin	Appleton	4.0	Fox River	97 per cent bacterial
	Milwaukee	54.9	Lake Michigan	U. S. T. D.
	Superior	2.3	Shallow wells	Less than 0.3 p.p.m.
Canada	....	....	....	....
Alberta	Edmonton	5.25 (Imp.)	Saskatchewan River	As clear and pure as
British Columbia	New Westminster	9.0	Mountain Lake, glacial	....
Quebec	Montreal	55.0	St. Lawrence River	Total count < 20
	Montreal	30.0	Ottawa and St. Lawrence River	99.9 per cent
Ontario	Ottawa	24.0	Ottawa River	Coli under 2 per 100
Philippine Islands	Manila	17.0	Mariquima River	As much improved a
		2859.4		

U. S. T. D. = Interstate Carriers Standard of United States Treasury Department.

* = Averages for 1916.

‡ = A particular day's results.

As low as possible in bacteria without producing bad taste and odor of chlorine	No	...	Rapid sand	...
B. coli absent in 50 cc.; total count below 20	Yes	10	Mechanical	110 m.g.a.d.
B. coli absent in 10 cc.	No	...	...	...
B. coli absent in 10 cc.; not over 20 bacteria at 20°	Yes	4	16 foot Jewell	125 m.g.a.d.
Free from B. coli	Yes	...	Mechanical	...
B. coli absent in 10 cc.; less than 50 bacteria	Yes	4	300 square foot area; mechanical	1 gal. sq. ft. min.
Normal carbonate alkalinity 3 to 6 p.p.m.	Yes	3	Mechanical	Normal
Less than 50 bacteria; no B. coli; turbidity color < 10	Yes	10	Mechanical gravity	125 m.g.a.d.
No free CO_2; bicarbonate alkalinity 8 to 9 p.p.m.	Sometimes	6	Norwood Engineering Co.	90–121 m.g.a.d.
3 parts free CO_2 when using alum; 4 parts monocarbonate alkalinity when using Fe and lime	Yes	34	Norwood Engineering Co.	1 m.g.d.
...	No	...	...	...
No B. coli in 100 cc.	Yes	...	...	...
Sterile; no turbidity. Color < 5.	Yes	12	Rapid sand	...
Less than 50	Yes	15	Maignon design	10 m.g.a.d.
No B. coli in 10 cc.; turbidity 0; hardness < 80	Yes	6	Rapid sand, 1 m. units	113 m.g.a.d.
Free from B. coli in 1 and 10 cc.	Yes	118	Slow sand	6 m.g.a.d.
		189	Rapid sand	
...	...	21	Slow sand	...
Maxima bacteria 10; color 10; alkalinity 6 to 7; turbidity 0	Not very	6	Rapid sand	1½ m.g. per unit
...	Yes	10	Slow sand, 1 acre	2–4.5 m.g.a.d.
Color 15; alkalinity 20; hardness 50	No	12	N. Y. C. J.	½ m.g. per unit
Count < 25; remove all B. coli type organisms	Yes	6	Mechanical gravity	125 m.g.a.d.
Count 10; no B. coli in 10 cc.	...	3	Mechanical gravity	...
Bacteria < 50; no B. coli	Yes	None	...	...
...	Yes	12	Mechanical	125 m.g.a.d.
U. S. T. D.	Yes	4	Gravity, rapid sand	125 m.g.a.d.
U. S. T. D.	Yes	None	...	...
Total count 10; no B. coli in 20 cc.; turbidity < 4	Yes	None	...	...
...	...	...	...	...
97 per cent bacterial reduction; no B. coli in 100 cc.	Yes	4	Mechanical	1 mg.
U. S. T. D.	Yes	None	...	...
Less than 0.3 p.p.m. Fe	No	3	Slow sand. 66¾ feet x 107¾ feet	6.75 m.g.a.d.
...	...	...	...	...
As clear and pure as possible	Yes	12	Roberts, gravity	6 m.g.d.
...	No	None	...	...
Total count < 20	Yes	16	Prefilters, rapid	
		16	Slow sand	
99.9 per cent	Yes	15	Gravity	2 U. S. gal sq. ft. m
Coli under 2 per 100 cc.	No	...	...	...
As much improved as possible	Yes	...	...	...

	125 m.g.a.d.	20 hours	High velocity washing	Effluent from filters	...	6–12 hours	6–
	...	...	...	Pump suction	Automatic	3 hours	<
	110 m.g.a.d.	48 hours	Water	As applied to filters	Automatic	18 hours	12
...	...	...	...	...	...	...	...
	125 m.g.a.d.	When needed	Water	Clear well	...	4 hours	N
	...	...	...	Pump suction	Automatic	...	...
ni-	1 gal. sq. ft. min.	24 hours	Water	...	Automatic	24 hours	2.
	Normal	48–60 hours	Air and water	...	...	$\frac{3}{4}$–2 hours	2.
	125 m.g.a.d.	24 hours	Air and water	Immediately before filters	Automatic	15 hours	15
	90–121 m.g.a.d.	50 hours	Air and water	Immediately before filters	Automatic	5 hours	12 24
	1 m.g.d.	24 hours	Air and water	Filter effluent	...	3 hours	20
...	...	...	...	...	...	...	...
...	...	...	...	Clear well	Automatic	...	...
	...	24 hours	Mechanical washing	Filter effluent	Automatic	3.5 hours	1.
	10 m.g.a.d.	When necessary	Back flush and raking sand	Filter effluent	...	1 hour	1
	113 m.g.a.d.	72 hours	Air and water	...	Automatic	6–12 hours	24
	6 m.g.a.d.	77 days	Hand scraping	Filtered water basin	...	...	...
	...	...	...	...	...	...	...
	$1\frac{1}{4}$ m.g. per unit	12–24 hours	Air and water	Filter effluent	Automatic	$3\frac{1}{2}$ hours	...
	2–4.5 m.g.a.d.	17 times a year	Hand scraping	...	...	...	...
	$\frac{1}{2}$ m.g. per unit	24 hours	Water	Filtered water flume	...	40 hours	8
	125 m.g.a.d.	24 hours	Water	Filter effluent	...	2 hours	16
	...	24 hours	Air and water	Filter effluent	...	3 hours	<
...	...	...	...	After 3 days sedimentation	...	3–4 days	3–
	125 m.g.a.d.	24 hours	Air and water	Before filtration	...	4 days	6
	125 m.g.a.d.	24 hours	Water	After filtration	...	3 hours	12
...	...	...	...	At reservoir outlet	...	...	24
...	...	...	...	Immediately before pumping	...	12 hours	72
...	...	...	...	...	...	...	...
	1 mg.	17–20 hours	Water	After filtration	Automatic	2.5 hours	10
...	...	...	...	...	Automatic	...	...
feet	6.75 m.g.a.d.	Average 16.3 days	Hand scraping	...	...	None	N
...	...	...	...	...	...	...	...
	6 m.g.d.	...	Water	Pump suction	...	4–5 hours	35
...	...	...	...	...	...	...	...
			Prefilters air and water; finals. Blaisdell machine	Main suction well	...	...	...
	2 U. S. gal sq. ft. min.	12 hours	Air and water	Filtered water	...	1 hour	N
...	...	...	...	Suction low lift	...	...	30
...	...	...	...	Intake	...	...	...

...	0–12 hours	0–12 hours	...	5–25	5–12	5–1000	0–tr.	0.01–0.05	0.01–.10	22–62	
				10	7	185		0.03	0.05	35	
atic	3 hours	<4 hours	Venturi (raw)	<10	...	15	...	Very low	...	90	..
atic	18 hours	12 hours	Venturi	29	4	58	0	...	...	170	
...	...	...	Venturi and pitometer	...	...	0	...	0.15	...	282	..
...	4 hours	None	Venturi	"Mud"	Clearer	50–1900	20–100	...	...	90±	
atic	...	...	Revolution counter	20	...	20	...	0.1–1.0	...	100–200	..
atic	24 hours	2.5 m.g.	...	23	0	40–1000	0	0–8	0	20–150	..
...	½–2 hours	2.5 m.g.	...	10	0	0–600	0	16.4	0.4	82–124	5
atic	15 hours	15 hours	Revolution counter	4–36	4–10	10–3500	0	2.0	0.5–1.0	85–120	7
atic	5 hours	12 hours at plant 24 hours down town	...	0	0	5–300	0	...	<0.2	...	2
...	3 hours	20 hours	Venturi	10–140	5–45	15–2500	0	0.1–3.5	Tr.–0.15	66–241	2
				45	13	164		1.5	0.1	156	
...	...	...	...	Clear	...	Clear	...	0.8	...	...	..
atic	...	...	...	0	0	0	0	0.1	...	120	..
atic	3.5 hours	1.5 days	Venturi	0–30	<5	2–110	0	...	...	100	
...	1 hour	1 day	Venturi	10–35	10	10–9000	0–3	1	...	80–140	..
atic	6–12 hours	24 hours	Venturi	Y–0–30	0–70	0–16,000	0	0.5–9.0	0–6	Acid	
				M–0–200	Trace	50		1.2	0.3	40–90	
										60	
...	...	...	...	...	...	...	...	...	...	...	..
...	...	...	Venturi	...	...	32.8	0.09	...	...	...	..
atic	3½ hours	...	Venturi	36–46	6–10	5–10	0	...	...	10–25	
...	...	...	Venturi	30–70	17–40	0	0	...	...	6–16	
				48	33					10.6	
...	40 hours	8 hours	Type "G" Simplex	130	18	3	0	1.0	0.05	12	
...	2 hours	16 hours	Pitot tubes	...	...	60–1500	0–4	...	...	6–22	..
						300	1			12	
...	3 hours	<24 hours	...	...	...	...	...	...	...	...	..
...	3–4 days	3–4 days	Revolution counter	...	...	100–3200	7	...	...	...	..
...	4 days	6 days	Revolution counter	...	0	5–6500	0	...	...	100–340	2
						400				192	
...	3 hours	12 hours	...	10–80	0–10	0–5000	0	0.3	0–0.1	200	
...	...	24 hours	...	0	...	0–100	...	0.1	...	10–22	..
...	12 hours	72 hours	Pitometer	20–50	6–20	4–500	0–7	Trace	Trace	8–70	
				35	10	52	4			37	
...	...	...	...	...	...	...	...	...	...	...	..
atic	2.5 hours	10 hours	Venturi	50	5	20–1000	0	...	...	160	
atic	...	...	Venturi	0	0	2–30	2–30	0.24	0.24	124	
...	None	None	Venturi	6–48	6–42	...	...	0.2–0.5	0.1–0.15	44	..
				14	13			0.3	0.1		
...	...	...	...	...	...	...	...	...	...	...	..
...	4–5 hours	350,000 gallons. Clear water basin	Venturi	...	Clear	0–6000	0–50	0	0	143–240	..
...	...	...	Venturi	Clear	...	Clear	...	0	...	...	..
...	...	...	Venturi	<20	<20	<20	<20	...	...	40–100	..
...	1 hour	None	Venturi	15–75	3–10	5–100	0–2	0.3	0.2	18–95	
...	...	30 minutes	Venturi	40	...	6	...	0.55	...	24	..
...	...	...	Venturi	20–40	...	0.8	...	0.2	...	100±	..

;	0.05	35	41	...	...	13,900	48	21.56 per cubic centimeter	0.0719
ow	...	90	...	106	19	...	...	...	...
...	...	170	51	...	...	8027*	24*	44 per cubic centimeter*	0.084 p
	...	282	...	0–9	...	3-7	...	1/13 in 10 cc.	...
...	...	90±	80±	9000	6000	40,000	27,000	...	...
.0	...	100–200	...	...	...	720	60	Present	Absen
;	0	20–150	...	200–210,000	0–180	2000–100,000	0–500	Up to 400 per cubic centimeter	0 in 1(
	0.4	82–124	50–90	1050‡	0‡	1540‡	0‡	Present	Absen
	0.5–1.0	85–120	70–105	...	...	500–350,000	0–120	95 per cent of 1 cc.	1/10 p
...	<0.2	...	20–30	10–70,000	2	100–500,000	4	20	
.5	Tr.–0.15	66–241	27–156	...	...	200–318,500	1–260	Index 23.42	Index
	0.1	156	63			22,002	34		
	...	...	...	4	...	...	...	0	...
	...	120	...	<200	<25	<500	<50	50 per cent of 10 cc.	None
...	...	100	98–99	40–200	0–4	200–6000	0–40	30 per cent of samples	
	...	80–140	...	...	...	Gel. 7000	38	Present in 1 cc.	...
.0	0–6	Acid	15–50	1400	7	3000	40	Y–35 per cent of 1 cc.	19 tin
	0.3	40–90	30					M–70 per cent of 1 cc.	year
		60							
...	...	...	...	...	...	...	...	...	...
...	...	...	...	...	...	Gel. 2167	48	...	...
...	...	10–25	6–20	200–1500	0–10	200–5000	0–10	0.0–0.5 per cubic centimeter	
...	...	6–16	6–15	100–25,000	1–150	...	...	Present in 1/100 cc.	Frequ
		10.6	10	1300	10				dom
	0.05	12	20	650	80	...	...	0	
...	...	6–22	...	300–2000	15	...	...	...	...
		12							
...	...	...	...	500	5–10	...	...	Present in 5 cc. in winter Present in 1/10 cc. in summer	0 in 1(
...	...	...	...	2500–3500	24–70	...	...	Practically always	...
...	...	100–340	20–180	...		Gel. 70–148,000	0–430	...	...
		192	96			6951	39		
	0–0.1	200	60	300	4–5	...	...	100 per cent of 1 cc.	<5 pe
	...	10–22	...	50–300	...	...	...	0–1 in 10 cc.	
c	Trace	8–70	8-45	250	12	...	...	...	...
		37	26						
...	...	...	...	...	...	...	...	...	...
...	...	160	152	100	3	2000	18	85 per cent of 1 cc.	4 per
	0.24	124	124	22–2800	1-85	1060–19,660	0–1440	98.2 per cent of 10 cc.	21.9 p
5	0.1–0.15	44	...	...	...	Gel. 0–220	0–30	Rare in 5 cc.	
	0.1					25.2	4.6		
...	...	...	...	...	...	...	...	...	...
	0	143–240	...	30–2000	0–40	Gel. 68–3200	0–1200	0	
	...		...	500–10,000	...	...	...	0	...
...	...	40–100	...	...		1700	17±	24 per 10 cc.	...
	0.2	18–95	6–90	6–5000	...	100–500,000	...	50 per cubic centimeter	...
	...	24	...	250	6	1049	12	66.8 per 100 cc.	0.26 p
	...	100±	...	760	336	...	...	0.15 per cubic centimeter	0.06 p

ubic centimeter	0.07198 per cubic centimeter			187	106			1.1	
...	...	...	...	...	...	...	5–12	...	...
ic centimeter*	0.084 per cubic centimeter	284	...	...	1206	...	5	...	752
) cc.	...	...	...	...	...	...	...	...	...
...	...	0–or 71–284	...	142–568	25	...	8	...	...
	Absent	...	...	...	...	...	8	1.8	...
per cubic centi-	0 in 10 cc.	...	...	Min. 213	...	...	...	4.1–6.2	...
	Absent	...	...	300	...	370	...	...	...
t of 1 cc.	1/10 per cent of 1 cc.	...	...	...	...	...	7.5	...	...
20	0	...	...	0–295	...	85–355	3–6.2	...	...
}	Index 0.011	152	...	238	...	667	6.2	...	...
0	...	...	...	...	...	...	...	...	...
of 10 cc.	None in 100 cc.	...	...	...	...	...	...	0.8	...
t of samples	0	28	...	...	...	...	3.5	...	...
1 cc.	...	383	...	...	...	...	...	1.5	...
ent of 1 cc. ent of 1 cc.	19 times in 10 cc. in 16 years	...	...	...	100–3800 866	...	...	...	0–1450 700
...	...	...	...	...	...	...	...	1.2	...
...	...	...	...	...	...	...	...	...	...
r cubic centi-	0	71–213	1–10 when used	...	...	...	2.5–5.0	...	14–35
1/100 cc.	Frequent in 10 cc.; seldom 1 cc.	...	...	...	...	...	...	...	...
0	0	284	...	...	...	94	16	...	...
...	...	220	...	...	...	...	...	...	...
5 cc. in winter 1/10 cc. in	0 in 10 cc.	625	...	...	...	...	...	5.0	...
always	...	142–426	...	...	...	...	7.1	...	...
...	...	...	...	210	450	...	...	3.0	...
t of 1 cc.	<5 per cent of 10 cc.	...	...	284	...	852	...	1.7	...
c.	0	...	2.8	...	...	...	...	...	...
...	...	100–560 245	...	...	...	...	...	1.66–4.92 3.05	...
...	...	...	...	...	...	...	...	...	...
of 1 cc.	4 per cent of 1 cc.	142	...	...	...	...	...	2.1	...
nt of 10 cc.	21.9 per cent of 1 cc.	...	...	...	...	...	...	2.0–3.1	...
c.	0	...	...	...	...	...	...	...	...
...	...	...	...	...	...	...	...	...	...
0	0	...	...	...	...	...	8–14	...	...
0		...	...	...	...	...	...	...	...
c.	...	...	...	...	...	...	5–20	...	...
ic centimeter	...	120	...	...	...	...	...	2.9	...
0 cc.	0.26 per 100 cc.	...	...	...	...	...	23	...	...
ubic centimeter	0.06 per cubic centimeter	...	...	...	...	...	8.3	...	...

and bacteriological work must be entered into. If the laboratory man is also an engineer, so much the better.

The author was surprised on first preparing his record to see how recently the laboratories listed had been installed. Beginning with the one maintained by the city of New York since 1897 and that of Utica, N. Y., established in the same year, a rapidly increasing number of laboratories was established during the succeeding 19 years. Six plants with a combined averge pumpage of 32.5 million gallons per day are now installing laboratories.

TABLE 3

Increase in laboratory control of water purification plants by plant or department laboratories

YEAR	AVERAGE DAILY PUMPAGE, HUNDRED MILLION GALLONS	POPULATION, 1910, MILLIONS	NUMBER OF PLANTS
1897	5.6	5.8	2
1898	5.6	5.8	2
1899	5.8	5.9	3
1900	5.8	5.9	3
1901	5.8	5.9	3
1902	6.2	6.05	5
1903	6.3	6.1	6
1904	6.6	6.4	8
1905	6.9	6.65	10
1906	.0	7.5	15
1907	8.6	7.9	17
1908	8.8	8.15	19
1909	9.5	8.85	26
1910	10.9	9.75	34
1911	11.4	10.1	41
1912	12.0	10.6	50
1913	13.1	11.5	57
1914	13.7	11.75	61
1915	14.7	12.50	74
1916	14.8	12.65	77
1917	15.5	12.75	83

Twelve plants with a combined pumpage of 45,000,000 gallons per day have daily examinations made at outside laboratories. The Metropolitan Water District which supplies Boston and some neighboring communities is under a state commission. It maintains its own laboratory and supplies a little more than 100,000,000 of gallons of water daily.

Of the plants reporting, 23 are owned privately, 72 municipally and one by the United States government. The employees of 29 of

the municipally owned plants and those of the government plant are selected by civil service methods.

Rivers and streams form the direct source of 68 plants out of the 96 that have their own laboratories, the remaining sources are lakes, impounded waters from more or less satisfactorily protected watersheds and, in a few instances, wells and infiltration galleries. Those plants which do not maintain laboratories are nearly all using the water of wells or impounding reservoirs. None of them supplies more than an average pumpage of 16,000,000 gallons per day. One or two pump directly from streams without treatment.

The quantity of the laboratory work done as well as the particular determinations made are dependent upon local conditions. For instance, there is very little use in determining iron every day unless the raw water contains that metal in sufficient quantities to precipitate or aid the growth of iron-secreting organisms.

Color and turbidity are usually determined on the raw and treated supplies if the water is coagulated and filtered. These factors give a somewhat rough indication of the efficiency of the treatment. Alkalinity is another common determination, since it limits the amount of coagulant which may be put into a water without the addition of alkaline substances such as lime, soda ash or bicarbonate of soda. Free carbon dioxide is carefully watched in some plants, particularly those that soften the water, remove iron, or use the iron and lime process. Incrustants and other matters are determined where the conditions justify.

Occasional complete sanitary chemical examinations are usually considered sufficient, since chemical standards based upon the ordinary factors of a sanitary analysis often mean very little when applied to the routine examination of a treated water. As a matter of fact the oxidation of nitrogen in one of our rapid sand filters is almost negligible and any evidences of pollution which appear in the raw water will be but slightly modified. This state of affairs has led to error on the part of individuals who have attempted to judge a treated water upon the basis of the commonly stated chemical standards. In the case of stored or impounded waters considerable oxidation may take place and the determination of the nitrogen factors may become of greater importance.

Mineral analyses are valuable to users of water for steam-making, but those individual firms which enter seriously into the problem of softening a supply usually make their own determinations of a few

important factors. There are quite a few boiler plants in most communities which use proprietary boiler compounds, prepared upon the basis of special analyses by the manufacturers of the compounds or upon the examinations of the laboratory of the water plant. Of course, an analysis of the city water showing its excellence for all industrial purposes is a good advertisement.

In general, however, it may be said that a quarterly mineral analysis, a weekly or monthly sanitary chemical analysis and routine determinations of color, turbidity, temperature, alkalinity, free carbon dioxide, free chlorine and the like, ought to meet all demands for chemical examinations. In discussing chemical determinations, very little reference to the procedures is necessary since the procedures laid down in the Standard Methods of Water Analysis of the American Public Health Association are so universally followed.

Plankton examinations are made by but 32 of the plants listed. In many cases they are not necessary. Where water is impounded or stored in open reservoirs, routine plankton examinations are useful in indicating the proper time for copper treatment before odors and tastes due to algae growths have become objectionable.

When working with a treated water, the bacteriological determinations are of the highest importance. In most instances they determine the efficiency and adequacy of the treatment given. The arbitrary standards of efficiency applied to water treatment are rapidly becoming more and more rigid. The original filters which the New Chelsea Water Company of London installed about 1829 were considered efficient if they merely removed the turbidity of the Thames water. Then a good many years later came Koch's standard of a maximum of 100 bacteria per cubic centimeter. This standard was applied to water of all kinds. Later a standard based upon a percentage removal of bacteria came into vogue. The percentage standard of plant efficiency is not satisfactory, because when one is treating a good raw water the product may show a low percentage efficiency and yet actually be of the best quality. On the other hand when the raw water is high in bacteria the effluent may be high also and still be within the limit set up. For example, 99 per cent efficiency in the operation of the Iowa City plant at one time last winter would have allowed a bacterial count of 8,800 because the raw water had a bacterial count of 880,000.

Within the past year or so, Wolman of the Maryland State Board

of Health has proposed a logarithmic ratio standard which has some advantages. It requires that the ratio of the logarithm of the number of bacteria in the raw water to the logarithm of the number of bacteria in the treated water shall not be less than 2.5 to 1. In effect it requires that as the contamination of the raw water increases, the efficiency of operation must increase at a more rapid rate. This standard undoubtedly has its limitations but it is a convenient device for supervision of operation of a number of plants.

At the same time that the strictly numerical bacterial standards of operation have been evolving, other standards based upon the freedom of the water from certain kinds of bacteria, such as the colon bacillus and the sewage streptococci, have been developing also. In this country the sewage streptococci have been worked with but little, while in Europe, particularly in Germany, the validity of American conclusions based upon work on the B. coli has been questioned. The author believes, however, that the present European tendency is to place more faith in the B. coli determinations than in the past.

There exists considerable difference of opinion as to the maximum number of bacteria of the colon type which may be allowed in safe water. The presence of B. coli in 1 cc. quantities of the water, except occasionally found organisms, is generally recognized as sufficient to condemn a supply. In addition it has been said that it should be absent from the majority of 10 cc. samples of the treated water. Constant absence in 5, 10, 50 and even 100 cc. has been recommended. A few years ago the United States Treasury Department standard for water supplied to trains carrying passengers in interstate traffic was promulgated. Briefly this standard required that a water should not contain more than 100 bacteria at 37°C. and that not more than one out of five 10-cc. plantings of the water into lactose broth should show the colon bacillus. This was practically equivalent to setting a limit for colon at one in 50 cc. This standard was adopted as the majority report of the committee appointed. It aroused considerable opposition from the water men when first adopted, but the government officials explained that it was not intended for city supplies, but for the small amount of water supplied to passengers. Since then it has been required that bottled spring waters and mineral waters should pass this Treasury Department test.

In the last column of table 1, under the head "Working Standard,"

are given the standards which the officials of the different plants have set up for their use. Many of these are working to the Treasury Department standard, a few are working to even higher standards, while some mention only a removal of turbidity and color. The author is inclined to believe, however, in these latter cases that some standard of bacterial purity was intended to be understood.

Some of the standards listed are very high and with some waters would be practically impossible to achieve except at a very high cost. This points to the fact that arbitrary standards are apt to be unjust in that they require all waters to reach a certain degree of purity which may not be essential to the safety of the supply.

The practical uniformity of procedure which can be noticed in the chemical determinations of a water analysis has not existed in the bacteriological procedures, due in part to the changes and ambiguity which were introduced by the committee into the second edition of the *Standard Methods of Water Analysis*. The third edition, which was published in 1917, is furnished with a much clearer statement of bacterial methods and no doubt will aid materially to clear away the confusion which exists.

In considering the methods used, the least variation will be found in the plating, because the possibilities for variation are not so great. In the body temperature determinations some workers use litmus lactose agar, which gives the opportunity of recognizing acid-forming bacteria in addition to the count, and others use the plain nutrient agar. At 20°C., many of the older laboratories use gelatine while others employ agar on account of its lack of trouble with liquefiers and its general convenience. In some laboratories the 37°C. or body count is omitted, while in more laboratories the 20°C. count is omitted on account of the recommendation of the committee in the second edition of *Standard Methods*. Fortunately the third edition has restored the 20°C. count.

In regard to the colon bacillus, there is the greatest diversity of method. Some are satisfied with gas formation in dextrose or lactose broth at the risk of calling a considerable number of tests positive when the gas formation is due to other organisms than the colon bacillus. Some prefer lactose bile. Others make confirmatory tests on all gas-bearing tubes. These confirmatory tests vary widely. They may consist in making simple streaks on litmus lactose agar or on Endo's fuchsine-sulphate medium, or they may extend to cultures in a series of sugar media, motility, Gram's stain and so on.

The new *Standard Methods* have prescribed a method using litmus lactose agar and lactose agar which will undoubtedly come rapidly into use and enable one to know on reading a report whether either of the two discriminating methods of identifying the colon bacillus have been adopted.

The chief business of most of the laboratories listed in the tables is the control of the water supply, but many of them further justify their existence by making examinations of other substances. Where time permits or sufficient assistance is provided, the chemicals used in the water purification may be made, as well as the coal, oils and so on. Purchases of these substances under the usual guarantees may be enforced, often at a considerable saving.

In city work, food and drug inspection, the milk supply and its inspection, the examination of cement, paving materials, and all city supplies may be put under the control of the laboratory chief.

Where the laboratory men are trained in that line of work, the city laboratory may make the examinations of the board of health's routine. These include specimens of blood for diagnosis of typhoid, sputum for tuberculosis, throat cultures for diphtheria and so on. Some of the last may be reported from ten to twenty-four hours sooner than the state laboratory could report, and a difference of this much time sometimes means saving a life.

The author has merely mentioned these possibilities of the extension of the scope of the laboratory to show how it can be made to serve the community in other fields. We, of course, should maintain that the first duty of the water laboratory is to maintain an economical treatment of the water supply which will insure a safe water at all times.

In the consideration of table 2 it is hard to draw general conclusions other than that most of the plants are operating efficiently. All do not treat the same sort of water by any means. The variation in turbidity, color, alkalinity and bacterial content of the raw water is very great. The turbidities range up to 12,000, the color to 480 and the alkalinity from -90 to $+580$. The maximum body temperature count of bacteria on the raw water is 210,000; the maximum of the 20° count is 1,000,000 organisms per cubic centimeter.

In going over the tables of chemicals used, the variation in the necessary doses is clear. The short summary of the figures on the next page is self-explanatory.

TABLE 4

	MAXIMUM IN POUNDS PER MILLION GALLONS	AVERAGE OF MAXIMUM FIGURES, POUNDS PER MILLION GALLONS
Aluminum sulphate	1275.0	334.5
Iron sulphate	850.0	349.0
Lime	3800.0	915.0
Hydrated lime	852.0	316.0
Calcium hypochlorite	20.0	9.5
Chlorine	6.5	3.2

Other factors of special interest are the sedimentation period and the storage period of the treated waters. For most of the rapid sand plants the coagulation period is less than six hours. About one-fourth of these plants have a storage of treated water of less than one hour—a condition which may often lead to difficulties in case of fire. The maximum storage of filtered water reported is as great as ten days, but the average is about six hours. The generally adopted rate of operation is 125,000,000 gallons per acre per day.

In conclusion, it should be remarked that the practice in the plants which are listed, is changing from day to day. In the time that the author has been collecting and tabulating these data, it is inevitable that some alterations have been made. The author has endeavored to make the tabulations as accurate as possible and he believes that they actually represent conditions in the water works industry up to the middle of 1917.